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JULY, 1942

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PRODUCT ENGINEERING

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IN THIS ISSUE

Aircraft Are Different

Contrary to the general impression, aircraft designs are not frozen, but must constantly be improved. In spite of this, production must be maintained on an even keel. This can only be done by making design changes in successive steps and by adopting production methods that permit design changes without requiring time-consuming and expensive retooling. At the same time production methods must be high in accuracy —in fact more accurate than those found in the manufacture of any comparable structure including the automobile. This month's lead article, "Aircraft are Different," explains how ingenious methods developed by the aircraft industry have achieved the apparent paradox of speed, accuracy, and rapid changes in design.

Contacts and Copper

The importance of good mechanical design in electrical equipment is dramatically brought out in this month's lead "Modern Designs" story. Subject: A large General Electric cam switch standing over 7 ft. high. Simple changes in the mechanisms and some clever redesign work resulted in a 50 percent reduction in number of contact arms required, and reduction from 72 to 29 in number of cams required. More important at present, copper bus work was virtually eliminated.

Springback in Flanging

Add to your design data files on bending and forming aluminum members the article "Springback in flanging," pages 382 and 383 of this issue. Authors are F. B. Chapman, T. H. Hazlett, and William Schroeder, research engineers with Lockheed Aircraft Corporation.

High-Strength Plastics

Big step forward, but still not a cure-all for the problems impeding widespread use of high strength plastics in

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load-carrying members, is the type of data presented on pages 379 to 381 of this issue. In good reference form are charts and diagrams giving strengths of molded and laminated materials to cover many of the conditions involved in design of mechanical parts. Eight commonly used Westinghouse compounds are covered by H. R. Moyer, of the Trafford Micarta Works.

Deflection of Beams

Supplementing the highly valued work done by Professor R. J. Roark on the calculation of stresses and deflections of various structural members, as covered in a series of articles in PRODUCT ENGINEERING back in 1936 and 1938, a new author, Mr. A. G. Strandhagen, analyzes a few more cases on pages 396 to 398 this month. Specific cases covered are beams under simultaneous axial and transfer loads. Mr. Strandhagen, who is in the Department of Mechanics at Carnegie Institute of Technology, presents a method for obtaining easily and quickly the solutions of differential equations involved. A good "meaty" article.

Sketches of Welding Design

Welding is a fabrication method that has often come through in the nick of time when shortages of cast iron parts have threatened. Sketched on pages 388 and 389 are 18 typical welded designs developed to meet war-caused shortages and to speed production. In some instances these methods proved more economical than casting. All of them contain helpful suggestions in the use of scrap and odds and ends in welded parts. Collector of these design details is Mr. E. W. P. Smith, consulting engineer for The Lincoln Electric Company.

Angles in Space

A graphical method for measuring an angle that does not appear in true projection on any of the three conventional views by orthographic projection, has been worked out by consulting engineer Herbert Stevens. The method requires only one auxiliary construction, on which not only one angle can be measured, but two or three angles and the true length of their sides as well. Mr. Stevens explains how it's done with simple geometric relations and constructions on pages 392 to 394.

Welding Deformations

Product engineers can do much to avoid the headaches of misfit parts and welded structures by planning the welding job in the drafting room. This may be a tough job. For instance, if two welders working on identical parts leave their work at different points to go out to lunch, the two parts probably will not be interchangeable. Gustaf Johansson of Link-Belt Speeder Corporation suggests ways by which the engineering department can specify standardized welding procedure to minimize distortions. Turn to page 390.

Sleeve Bearings—III

Continuing the series begun in PRODUCT ENGINEERING for May, the third part of the article by Bruno Sachs, Technical Director of the Johnson Bronze Company gives an enlightening discussion of many factors that should be considered by engineers when selecting materials for bearings. Among the most important questions answered are: How does the bonding and backing technique affect the performance of the bearing? What types and shapes of oil grooves are best for various classes of service? Answers on pages 384–387.

Specifications for Copper Alloys

With specifications for copper alloys numbering in the hundreds, it is often desirable to know just what specifications apply to the various alloys, which alloys are comparable, and whether they apply to rods, plates, sheets, tubing. This month's Reference Book Sheets, pages 423–426, clarify the situation by comparing 140 listings of A.S.T.M. numbers, 100 each for the Federal and Navy, 57 for the Army, and 140 more divided among the A.S.M.E., S.A.E. and other organized agencies. These pages were prepared by R. A. Wilkins and E. S. Bunn.

WHAT'S COMING

The Amazing Imitators

The Japs have taken Pratt & Whitney pistons, Wright cylinders, General Electric impellers, Eclipse impeller casings, etc. ad infinitum, and out of a jumble of American and German design details have developed a "good" engine. In their imitation they show great ingenuity although little originality. But don't be fooled. They have lots of originality. By leaving off armor plate, and making the plane as small as possible so as to take advantage of the small racial stature of the Japs, they have created their well known Navy Zero fighter—a plane that is lighter, has more horsepower per pound, and is more maneuverable than fighter planes we can send against them. PRODUCT ENGINEERING will tell this story in greater detail next month.

Riveted Joints

Just because one rivet is good for 1,000-lb. loads it does not mean that 10 rivets will carry 10,000-lb. loads. It all depends. Ezra C. Posner of Lockheed will show how to analyze a joint, and all it requires is simple arithmetic. Results are sometimes startling. In a 12-bolt joint analyzed as an example, one of the bolts carries 242 percent of the average load per rivet.

Critical Speeds

To calculate the critical speed of a machine element usually does not involve any great difficulty. Much has already been written on this. The headache comes when it is necessary to calculate the critical speed of a mechanism or machine. Next month C. R. Freberg and E. N. Kemler, both of the School of Mechanical Engineering at Purdue University, will present a relatively simple procedure for doing this. General formulas will be given which can be applied to any generalized problem of this type, together with actual detailed calculations.

Materials Data

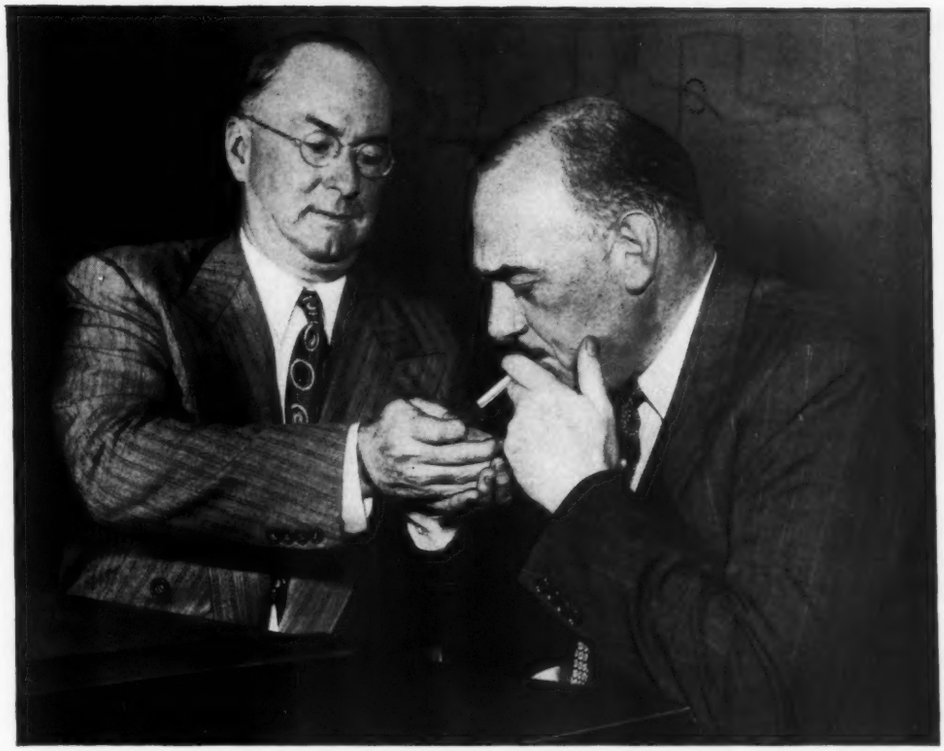
Cobalt has one of its most important uses as an alloying agent in permanent magnets. The need for conservation of this metal has prompted the preparation of a report to the Office of Production Management, discussing conservation. Briefed on pages 399–402 of this issue.

American spring steels have not yet equalled Swedish steels in fatigue limits. However, a number of substitutes are being used with reasonable success. For recommendations see pages 405–406.

So-called "tinless solders" have been suggested as suitable substitutes for tin solders. Some of these may be objectionable for high speed can soldering, but they may be used in many other applications. See pages 403–404.

If machinability is of importance in brass, the addition of lead is the answer. For flaring, cold heading, or bending, lead must be avoided. The properties of brasses for both of these applications are charted in this month's Wilkins-Bunn brass series, pages 407–410.

The Story That Must Be Told



Two men who know the story best: Donald Nelson, Chief of the U. S. War Production Board, and (right) Oliver Lyttelton, Great Britain's Minister of Production.

BETWEEN THE LINES of today's war news is written a story that is even more vital than the news itself. For through that story we begin to discern the pattern of victory, not yet complete in all its details but increasingly clear in its essentials.

It is the amazing story of how American industry has responded to the call for the weapons of total war, of how its technicians, workers, and managers are driving through an unprecedented task of fantastic size and complexity.

France fell in June 1940. During that month this country produced about $150,000,000 in war goods. By June 1941 the Nazis had overrun the Balkans; and in that month our war production was $800,000,000. The fateful month of December 1941 gave us an output of $1,800,000,000—an increase better than tenfold in eighteen months. And in May 1942 our total expenditures for war equipment and supplies mounted to the staggering total of $3,500,000,000.

This is an increase of twentyfold within two years, of itself a stupendous industrial achievement. But what is even more important, that achievement already is making itself felt the world over—in the Orient, in Australia, in Libya, in Europe, in the Coral Sea, at Midway Island, at the Aleutians, and wherever else we find a battlefront manned by free men.

To accomplish it, many industries have been pouring out war materials at a rate that only six months ago did not seem even remotely possible. Starting from scratch, our factories have turned from their peacetime jobs, first to meet and then to surpass the most hopeful estimates of what might be expected of them.

To do this they have drawn heavily upon all of their resources. Their skilled and unskilled

man-power has thrown into the task a war-born will to work; their research staffs have bent to it all of their scientific resources; their engineers have applied to it their utmost ingenuity; their executives have devoted to it the full measure of that managerial skill which has won for American industry the respect of the modern world.

For the first time in history we have pushed the accelerator of the world's greatest engine of mass production down to the floorboard. Always in times of peace, factory men have had to gear production to what the markets would take. But now the market they are called upon to serve is hungry for the last ounce of potential output. For war confronts industry with a demand limited only by its capacity to produce.

During these feverish months, while a desperate world has watched breathlessly to see how American industry would perform as the arsenal of democracy, we of McGraw-Hill have followed with mounting pride — at times almost with wonder — a new miracle of industrial achievement.

Some day the full story of this American industrial effort will fill a brilliant chapter in the epic history of our times. Meanwhile it would be premature to celebrate the completion of this task. For victory has not yet been won; that still lies at the far end of a road that we may find to be long and arduous.

But even now we can be certain of one essential of that victory. American industry is doing its job; it is delivering all that the people have asked of it — and more.

As I have watched with my associates the unfolding of this picture, I have wished that it were possible to broadcast it, in full color and wealth of detail, to the people of America, so that they could understand at least, in part, the job their industry is doing for them. It would help, it seemed to me, if the men of industry themselves, each so intent on his own task, knew what their fellow-workers in other fields have been doing.

However, the managers of industry have been far too busy **doing** to talk. They are going to be just as busy for some time to come. Naturally, many details are yet to be spread upon the record and, indeed, the full story cannot be told. But that part of the story that can be told is well worth the telling and the hearing, if only for its revelation of the spirit of an awakened America, throwing its all into the fight against the tyranny that has brought so many of the world's little people under its heel.

The 1941 war production of the United Nations, exclusive of the United States, equalled the total 1941 war output of Germany with all of its captive plants and enslaved labor. Since Germany's 1941 operations were at maximum capacity no further increase is possible. British output has been expanding to the point where its 1942 production is considerably ahead of Germany's.

In May 1942 American war production passed the British output 50 days ahead of schedule. In 1943 it will be 3 times that of the British.

This has been brought about under the leadership of Donald Nelson and the War Production Board, the Army, the Navy, the Maritime Commission, with the cooperation of management and labor. It has been furthered by the cooperation of Oliver Lyttelton, British Minister of Production, and other British production authorities.

But the story goes far beyond that. It gives us a glimpse of the America as it will emerge from this war, its industries again setting world standards of production, which will become the spearhead of our post-war economy.

This is a story that cannot be adequately told in generalities. It must be told in some detail. For instance, the great accomplishments of the machine tool industry, the great forward strides made by the aviation industry, the tremendous achievements of the chemical industry, the amazing conversion of many industries will warm the hearts of Americans.

These aspects of the subject deserve the fullest treatment and will be told month by month in these pages until the story has been completely unfolded. We will try to give a concise overall picture of the war job that industry has done and still is doing. You will find it a thoroughly American story of high American achievement in which every American can take pride and from which every American can take hope for the future of his country.

The story is far too significant to be withheld any longer.

James H. McGraw, Jr.

President, McGraw-Hill Publishing Company, Inc.

This message is appearing in all McGraw-Hill industrial and business publications, reaching over a million readers.

PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

The Best Is None Too Good

IT IS FOOLISH TO SAY that this or that will win the war. Only the men at the fighting fronts, on land and sea and in the air, can win this war. The best that the non-combatant civilians can do is to put forth maximum effort and willingly sacrifice to make possible an early victory.

The patriotic duties of all civilians are clearly defined. In addition, many men and women engaged in various activities have further obligations, such as the responsibilities of those working at the all-important production of war equipment, both its design and manufacture.

Engineers and production men far from the scenes of battle can hardly fully appreciate the importance of having jobs done right. The old saying, "For the want of a nail, the shoe was lost, for the want of a shoe, the horse was lost . . ." has more applications in this war than in any previous one. The jamming of a gun, a loose connection in an airplane, a poorly designed turret, an inefficient transmission, a radio transmitter that doesn't function or any one of thousands of other possible defects might mean the losing of a battle instead of the winning of a continent. Tens of thousands of brave determined men might lose their lives because they put faith in something which failed at a crucial moment.

No job is ever finished and perfection is never reached. Nor is there a definite limit to the human effort which can be put forth to reach a desired goal. Today innumerable engineers are giving to their jobs all the time, thought and effort possible. But more can be done and more must be accomplished. It can come only from increased enthusiasm, greater determination and a fuller appreciation of what is at stake by those who have not reached the peak in their efforts or who have let down a little because victory seems to be in sight.

But victory is not yet in sight. The scattered victories over Japan cannot have decisive effects at this time. The wishful thinking concerning an early crack-up of the Nazi war machine has no sound basis. The hope that the conquered people will rise in revolt and overwhelm their oppressors is not possible of realization until the armies of deliverance have set foot in Europe. The blasting of German war factories will not in itself silence the guns of the enemy.

Thus as we begin this 167th year of our independence, let us take sober thought. The New York *Times* editorial, "What's A Flag?", reprinted in this issue, splendidly portrays our heritage and what we have at stake and clearly implies that the present is not a time for wishful thinking and foolish talk. Rather, we should think of the closing words in the Declaration of Independence, "To this we pledge our lives, our fortunes and our sacred honor." With this thought uppermost, may the men and women upon whom our fighting men depend for the world's best war equipment, and enough of it, renew their determination, enthusiasm and efforts. The men doing the fighting will win but only if we give them the material to do it with.

Lockheed's final assembly line for "Lightning" P-38 fighters needs no chain conveyor. Planes roll from station to station on their wheels

AIRCRAFT ARE DIFFERENT

No Other Industry Has Comparable Problems

G. F. NORDENHOLT
Editor, Product Engineering

Men in the aircraft industry will find nothing that is new to them in this discussion of problems and accomplishments in the manufacture of military planes. But engineers not thoroughly familiar with aircraft manufacture will be impressed with the striking simplicity and efficiency of the manufacturing methods described and which permit significant design changes with practically no loss in the rate of production and incurring little cost for tool changes or new dies.

OTHER than the engineers who are engaged in or associated with aircraft production, it is not generally recognized that there is a vast difference between the building of aircraft and the building of automobiles. Although many people recognize the obvious difference underlying the production of these two structures, not many recognize the production restrictions and requirements imposed by the absolute necessity for flexible engineering designs and production methods.

When it first became obvious that the United States would have to build a huge air fleet there was a great deal of shouting about "freezing the design," the implication being that with the designs "frozen," aircraft production would be put on a basis similar to automobile manufacture. It is true that types of military planes have been frozen to some extent, but to freeze completely the designs of such planes would invite disaster. The useful life of a military plane is, at the present time, about 1½ years. The various basic models of military planes such as P-38, P-40, B-24, B-25, PBY and all other important ones have, since the beginning of the accelerated production schedule in June 1940, gone through as many as eight model changes, each succeeding model being definitely superior to the preceding model with reference to features such as speed, maneuverability, fighting power, protective armor, load-carrying capacity, cruising range and similar all-important characteristics. One of the major problems in the production of military planes has been to make such changes with a minimum loss of production. This has been accomplished but could not have been accomplished if the pro-

duction methods were not sufficiently flexible. Steel dies, elaborate assembly jigs and all the other embellishments necessary for mass production "a la Detroit" would either kill all further design improvements or torpedo the production schedules. Either would be disastrous.

Before the start of this big order aircraft production program, military planes were ordered in lots of only a few. An order for 50 planes was considered a big one. Therefore, at that time, the production methods had to be based upon minimum cost of dies, assembly jigs and other tools. This compelled the aircraft industry to develop many ingenious ways by which to produce complicated shapes with minimum tool costs but maximum speed. Instead of using steel blanking dies to cut irregular shapes, the sheets were profiled to the shapes desired by a routing tool similar to the routers used in the woodworking industry. It is interesting that today substantially the same method is still being used, although greatly improved, and will probably continue to be used for the protection of most of the blanks.

Advantages of Routing

In one important respect, routing is far superior to blanking with steel dies. A steel blanking die produces a part with relatively rough edges, the action of the steel die causing fine scratches across the thickness of the sheet. The scratches become points of stress concentration during the later forming of the sheet. Quite often the die-blanked aluminum sheet will crack during the subsequent forming operation because of this stress concentration. This fact was soon discovered when the aircraft industry began using steel punches and dies for blanking.

In cutting the blanks with a router, any scratches made by the tool are substantially parallel to the surface of the sheet. Therefore, such scratches will not serve as points of stress concentration and the sheet will not crack in subsequent forming operations. But this is only one reason why the aircraft industry is still using the old routing method for forming blanks and will probably continue to do so. Of course, the method has been greatly improved through the use of router boards and special machine set-ups. Faster production has also been achieved by stacking the sheets and profiling a number of them in one operation.

Routing out the blanks instead of using steel blanking dies greatly simplifies the problem of making improvements in the design of the plane. If design improvement calls for a change in the profiling, it is merely necessary to change the shape of the router board or make a new one, either of which involves little time or cost. On the other hand, to change a steel blanking die involves expensive machining operations, usually requires an entirely new punch and die, and at the best takes a long time. Besides this, skilled tool and die workers are at a premium. If, in the building of aircraft, it were attempted to supplant router boards with punches and dies, the industry would soon be hopelessly bottlenecked by the toolroom or the design engineers would be thwarted in their development program.

Rubber Forming Dies

Many people have derided the use of rubber forming dies, the Guerin process, and have labored under the impression that such a production method is merely a makeshift. On the contrary, it is a highly scientific operation and undoubtedly is the best process that can possibly be used unless we are to freeze completely the design of aircraft and make impossible the continuing program of improved designs such as is now being followed. The reason becomes obvious when one considers the operation of forming pieces in the hydraulic press with its rubber die. Actually, a die is not used. In its simplest form, a block of Presswood or similar material is profiled to the outline of the interior surface of the panel section, cup shape or whatever shape is being produced. The thickness of the block is equal to the depth of the panel, cup or impression. This die block is placed on the surface of the stationary bottom platen of the hydraulic press. The sheet of aluminum, profiled to the proper shape, is placed on top of the wooden die block, being held in the correct position by pins in the die block passing through locating holes in the aluminum sheet. The upper platen of the press has a thick rubber pad that fits snugly into a steel frame so that the rubber cannot bulge out laterally. When the top platen of the press comes down on the wooden die block with its aluminum sheet, the sheet and die block are pushed into the rubber and the rubber squeezes the sheet tightly against the side walls of the die block. This is known as the Guerin process.

The Guerin process has been speeded through the use of large presses that permit a number of pieces to be formed simultaneously. Also, no time is lost in taking out the finished pieces and arranging another set-up on the platen of the press. The pieces are arranged on a large circular rotating table which slides across the platen of the press, or on a long straight reciprocating table like a log-sawing table. At one station the die blocks and blanks are positioned and made ready for the next pressing operation. At another station, the finished pieces are taken off. Simultaneously, the forming operation takes place at the station under the press platen. At the end of the forming operation the table is slid to the next position.

Obviously, this production method has many advantages. The die blocks cost little and can easily be altered with little loss of time and at a small cost. A number of pieces of the same design can be formed simultaneously because of the low cost of the die block. This is economical. Steel forming dies would be expensive and for most forming operations they would have to be complicated by the addition of a spring pad. But worst of all such forming dies would inevitably freeze the design of important details of the airplane structure.

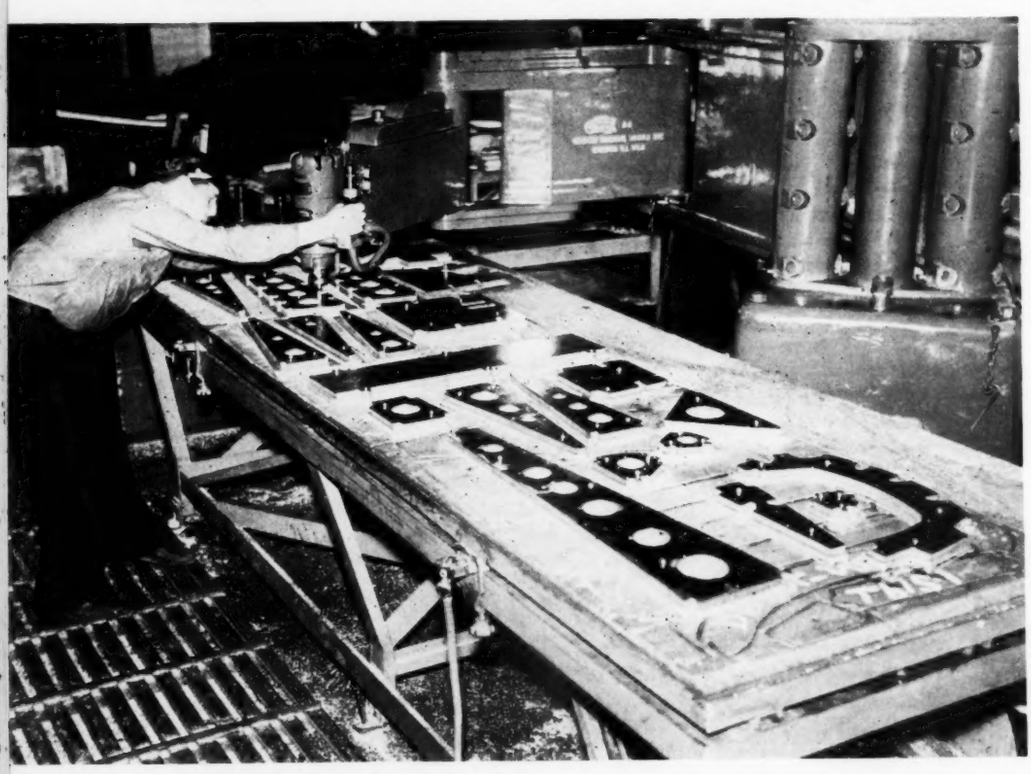
As pointed out by J. L. Atwood, executive vice-president of North American Aviation, Inc., in his talk at the recent spring meeting of the American Society of Mechanical Engineers: "Only 3½ percent of the labor hours in the average airplane are expended in forming sheet metal parts." Mr. Atwood went on to explain that if steel dies were set-up on presses and all the units required for the whole contract were made, say 1,000 pieces of each unit to fill an order for 1,000 planes, practically all the aluminum required for the whole order would have to be delivered before a single plane could be finished.

Insofar as labor cost is concerned, for short runs or medium-size lots the time required for setting-up a steel die is generally more than the total required to make the parts on wooden die-blocks.

High Degree of Accuracy

In the various assembly operations, the conditions are entirely different from those prevailing in the automobile industry or in other metal manufacturing industries. The size of the parts involved are much bigger and they must be made more accurately. A body of an automobile is less than 10 ft. long. An airplane unit may be 30 ft. or longer. A high degree of accuracy, as compared to that required in the aircraft industry, is not essential in the manufacture of automobile bodies. Whereas a bomb bay door must be a perfect fit, the average automobile owner is satisfied if his door closes with a crack remaining. The various sub-assemblies of an airplane such as the wings and fuselage sections, must be interchangeable and fit almost exactly. If they do not fit,

Forming sheets by stretching them over a form on a hydraulic machine requires little die equipment. Here is shown the operation as done in a Curtiss-Wright plant



Cutting blanks with a router is not a slow operation. This high-speed router in a Curtiss-Wright plant is cutting stacks of blanks all profiled to size and shape as determined by router board clamped on top of aluminum sheets

they cannot be made to fit by pounding with a mall or bending the sheets, a practice sometimes resorted to in the automotive industry.

The accuracy required in the aircraft industry in assembling the pieces is indicated by the design of the assembly jigs used. When airplanes were small the jigs were bolted to the floor of the shop but when bigger jigs were required it was soon discovered that the movement of the floor, although not measurable by ordinary means, was enough to throw the jigs out of proper alignment. Therefore, all assembly jigs are now made as a complete self-supporting unit and sit on the floor on adjustable legs. The jig is built so rigidly that it will not distort, in spite of which it is deemed necessary to carefully check the jig throughout all of its dimensions at regular intervals.

Although the assembly jigs used are large and heavy, considerable thought must be given to make it possible to modify the jig at a small expense in case it should be found desirable to change some detail in the design of the unit to be assembled on the jig. This is a basic consideration throughout all of the steps in aircraft production in order to make feasible continuing design improvements.

In the final assembly stages of the airplane, new technique had to be developed in order to avoid difficulties. Here again conditions caused by the size and required accuracy of the structure have made aircraft assembly entirely different from that of any other structure. Rivet holes must match to a high degree of accuracy. But if a long line of rivets were to be driven in the usual manner beginning at one end and proceeding to the other end, the alignment of the holes would be destroyed before many rivets were driven. This is caused by the creep of the sheet metal when it is subjected to the pressure of the rivet hammer. With the driving of each rivet, either one sheet or the other would creep to a greater amount, the cumulative effect of which would soon throw the two sheets entirely out of alignment. This situation is avoided by driving the rivets at intermediate points.

Growth Brings Progress

Whenever criticisms are launched against production methods and design of aircraft, it should be borne in mind that in any growing industry one change makes possible other changes. For example, up to the time of the adoption of the large hydraulic presses, forming operations were costly and slow. For this reason design engineers avoided as much as possible any constructions that would involve difficult forming. Thus, instead of designing a part to be made by flanging a sheet, the practice was to design it to be made as a flat sheet and then rivet angles to it. Similarly, because it was expensive to emboss a sheet to stiffen it, the solution was to use a flat sheet and rivet on angles, channels or other roll-formed sections. But today the Guerin process used with large hydraulic presses has greatly reduced forming costs and the designs of many parts are being modified accordingly. For example, a previous design of duct section required 28 pieces riveted to a flat sheet bent into a U-section. The 28 pieces, which were small rolled channels, were solely for the purpose of stiffening the sheet. The same duct section is now made of one piece, a

flat sheet embossed to give it the desired stiffness and then bent to a U-shape. Similarly an open box-shape sub-assembly formerly consisted of 9 pieces, namely, 2 pieces of sheet with 7 angles riveted along various edges to provide flanges. That sub-assembly is now made in 2 pieces, the angles being provided by flanging the edges of the box section.

Such design improvements have two purposes. Not only do they speed production but they also decrease the weight of the finished structure. The simplified designs of the duct section and box section referred to above saved a total of more than 3 lb. in weight. When such savings are multiplied by simplifying the designs of numerous other parts, as is being done, the total saving may be equivalent to the weight of several bombs, many miles increased cruising range, or the addition of armament or fighting power. It is only by keeping at it constantly and improving a detail here and another one there, that the designs of American military planes are being kept ahead of those of the enemies.

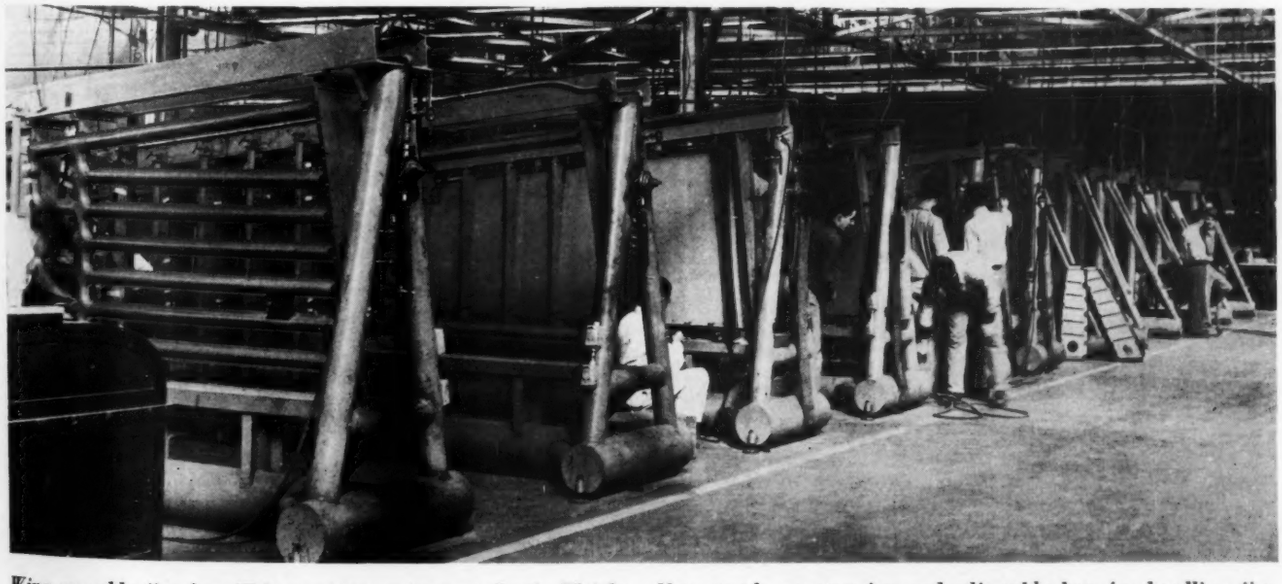
Referring to the statement that airplane designs are frozen, the number of design engineers now engaged in improving American military planes, refutes that statement forcibly. Mr. J. L. Atwood, in his above quoted speech, stated that, "now there are actually more designers working on improvements than were required to produce the original design." Exclusive of clerks, blueprint boys and secretaries, the number of design engineers ranging from draftsmen to engineering executives now employed by the major aircraft companies ranges from 800 to 1,500 in each company.

As a conservative estimate, considerable more than 12,000 engineers are now engaged in the continuous improvements of the design of the American military planes. In addition to these engineers, there are those that are engaged in the continuous improvement of the airplane engines, the propellers and the hundreds of accessories that enter into a complete ship. The sweat and brains of these thousands of engineers will maintain the supremacy of the designs of American military planes. But this manpower cannot produce effective results unless the production methods in aircraft manufacture continue to be such that design changes can be made without seriously interfering with production schedules. That is why steel dies have limited use in aircraft manufacture, and why rubber pads, wooden die blocks, zinc dies, router boards and similar methods sometimes derided by the uninformed, must continue to be used. And that is why the American aircraft industry has been able to build up to its present large production in spite of the fact that at the same time it developed and put into production a succession of new models, thus attaining air supremacy in both numbers and quality of planes.

Willow Run

Whenever anybody quotes the expected production figures for the Willow Run plant of Henry Ford, several factors should be borne in mind. The Willow Run plant was designed and equipped for the production of a specific type of aircraft and that type only. Practically all of the old line aircraft plants were designed to produce a number of different types. In the design of the Willow Run plant, it was possible to lay it out and equip it with only one production problem in mind, namely the problem of producing that particular type of bomber. Secondly, the designers of the Willow Run plant had all the benefits of the decades of experience of the best engineers in the aircraft industry and Ford production engineers today are receiving advice from and consultation with the best engineers of the aircraft industry.

The production technique adopted at Willow Run is nothing that is entirely new except as to magnitude. The same type of production procedure had been developed and tried at other airplane plants. In various other forms it is being used at all the major plants. The amazing record that Henry Ford will undoubtedly pile up in the production of aircraft is not to be belittled but, on the other hand, the accomplishments of the old line aircraft companies should not be derided for that reason. The Ford project is notable more as an example of another great achievement of American industry wherein the talents of management, engineering and production of a number of companies are brought to bear on the solution of the problem at hand. More power to Henry Ford and his Willow Run plant. But it must be remembered that without the skill and technique developed by the aircraft industry over its decades of experience there could not be a Willow Run plant such as the one we have today. But it must also be recognized that only the daring, initiative and imagination of the type of Henry Ford, plus the resources in money, brains and organization such as that possessed by the Ford Motor Car Company, could successfully achieve a bomber production such as that at Willow Run.



Wing assembly jigs for AT-9 transition trainers at Curtiss-Wright. Note sturdy construction and adjustable legs for levelling jigs

Modern Designs

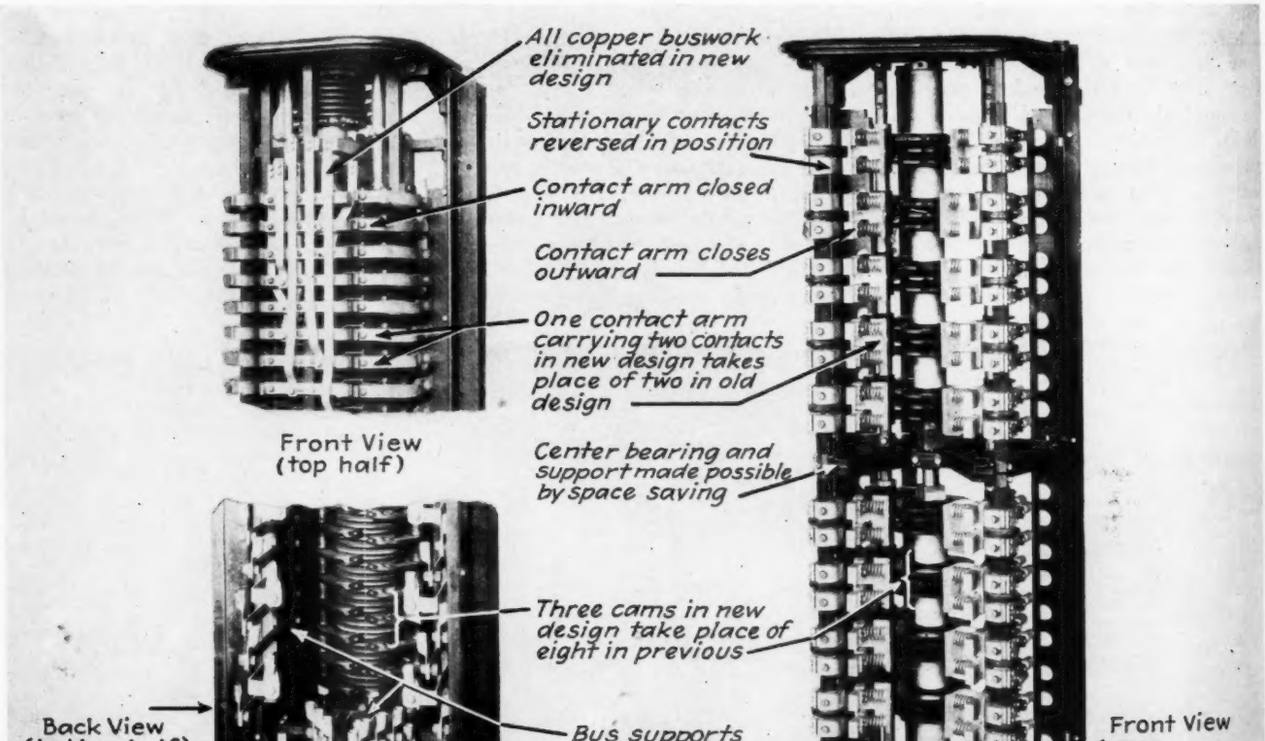
Simpler Switch Mechanisms Save Materials

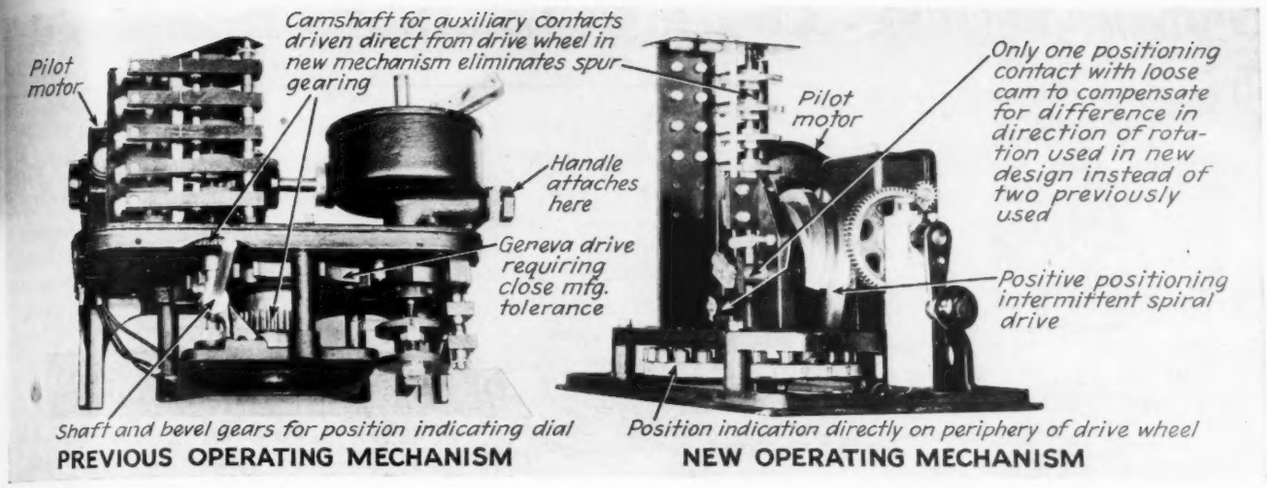
Changes in mechanical design of this General Electric cam switch resulted in elimination of large amount of copper bus work, 50 percent reduction in number of contact arms required, reduction from 72 to 29 in number of cams required, considerable simplification in the drive and control mechanisms, and more rigid and accessible construction. These cam switches are quite large, standing over 7 ft. high, and are rated at 600 amp., 1,000 volts for secondary control of wound rotor induction motors.

Number of cams is reduced by: (1) 50 percent reduction in number of contact arms achieved by mounting, on one contact arm, the two movable contacts which establish the third leg of the "Y" external rotor circuit, and (2) using one closing cam in place of two for two contact arms mounted on opposite sides of switch. This is accomplished by laying out the 20 switch points in 15-deg. increments and having contact arm for 11th point opposite contact arm for 1st point with 165 deg. spacing between actuating rollers on these arms; thus the same closing cam that is in position to close contact No. 1 on 1st point will be in position to close contact No. 11 on 11th point.

Copper bus work was eliminated by reversing the action of the contacts so that they close outward instead of inward. With stationary contacts previously located in the middle at front, it was necessary to run a bus bar from each set to the back of the switch. In new design, stationary contacts are mounted at the sides, where they are accessible for connections from the back. Flexible shunts are carried directly to the back in either case.

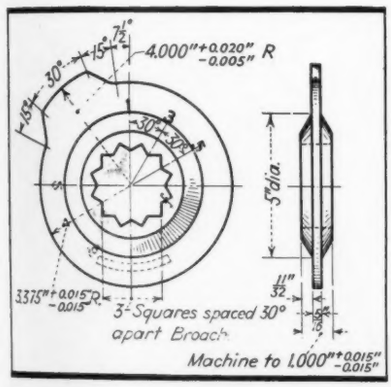
Elimination of so large a number of parts left room for addition of a central bearing support on camshaft. This reduced deflection of shaft when contacts were closed, thus increasing amount of contact wipe and wiping pressure. Accessibility and ease of servicing were also increased.


All copper buswork eliminated in new design
Stationary contacts reversed in position
Contact arm closed inward
Contact arm closes outward
One contact arm carrying two contacts in new design takes place of two in old design
Front View (top half)
Center bearing and support made possible by space saving
Three cams in new design take place of eight in previous
Back View (bottom half)
Bus supports eliminated
Front View
PREVIOUS CAM SWITCH
NEW CAM SWITCH

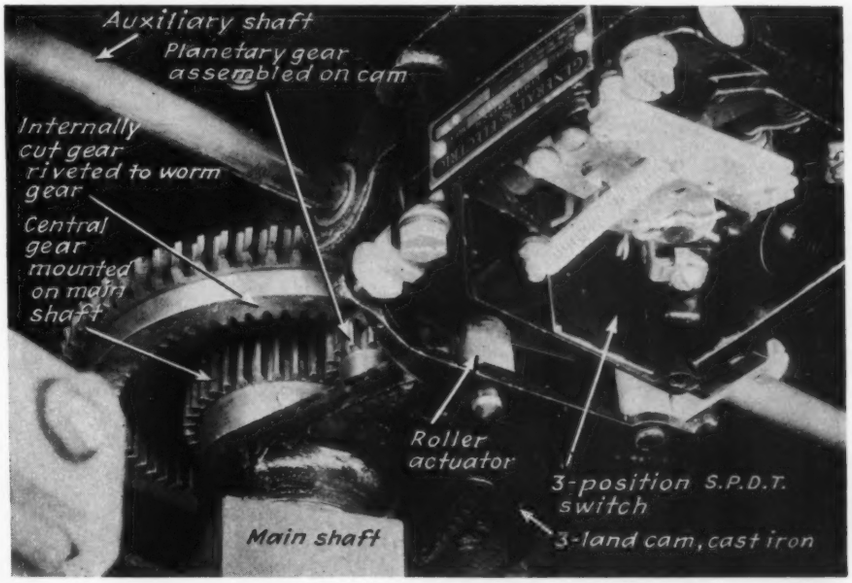

Pilot motor
Camshaft for auxiliary contacts driven direct from drive wheel in new mechanism eliminates spur gearing
Handle attaches here
Geneva drive requiring close mfg. tolerance
Shaft and bevel gears for position indicating dial
PREVIOUS OPERATING MECHANISM
Pilot motor
Only one positioning contact with loose cam to compensate for difference in direction of rotation used in new design instead of two previously used
Positive positioning intermittent spiral drive
Position indication directly on periphery of drive wheel
NEW OPERATING MECHANISM

Intermittent motion for positive point-to-point operation is now an intermittent spiral drive cam which engages rollers located on the periphery of a driven wheel. This intermittent cam has lead for about 25 percent of its circumference; remainder is straight land which stays in engagement between two rollers. Previous drive was Geneva mechanism which required close manufacturing tolerances and which gave trouble when worn. The change permitted much simpler position indicator. A numbered strip attached to periphery of the driven wheel now replaces a numbered dial mounted on a shaft driven by bevel gears. Positioning contacts, which stop the motor at the correct point in the revolution of the spiral gear, have been reduced from two to one. Two positioning contacts, one for each direction, were used previously to allow for difference between points of engagement and disengagement of pin gear with Geneva wheel when rotating in different directions. The one positioning contact now used is tripped by a loose cam driven by a dog assembled to the shaft. Since dog engages cam from opposite sides, thickness of cam controls difference in opening points of the contact for the two directions.

Simplification of intermittent mechanism also made possible simpler drive for auxiliary contact shaft which actuates end limit and interlocking contacts. Shaft now is driven directly from top of driven wheel by means of an arm which is attached to auxiliary shaft and which engages between two pins on the driven wheel. Previous drive was through spur gears to separate contact shaft.



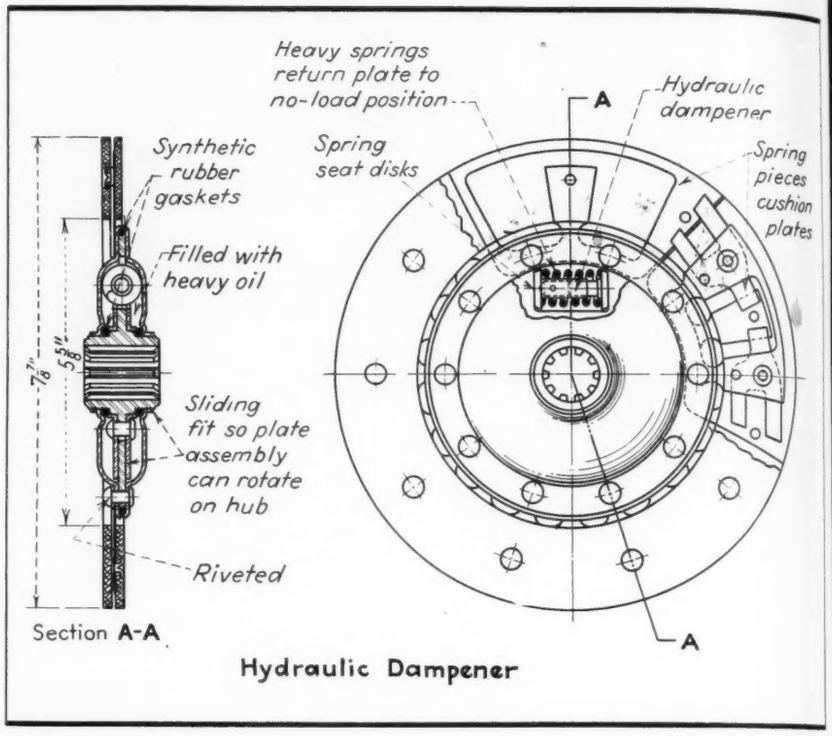
Only two different cam shapes are required in the new switch; whereas a different cam was required for each set of contacts closing on different points in the old switch. Present cams, one for opening, the other for closing the contacts, are mounted on square shaft. Hole in center of cam is equivalent to three squares set 30 deg. apart. Rise in cam contour is spaced 7½ deg. away from corner of one square. Without turning the cam over, it can be assembled on the square shaft to give actuating positions spaced 30 deg. apart; by turning the cam over the intermediate points can be set. Thus one cam contour can be set to any of the 15 deg. points on the switch. In the two standard cam forms, rises and falls are reversed.



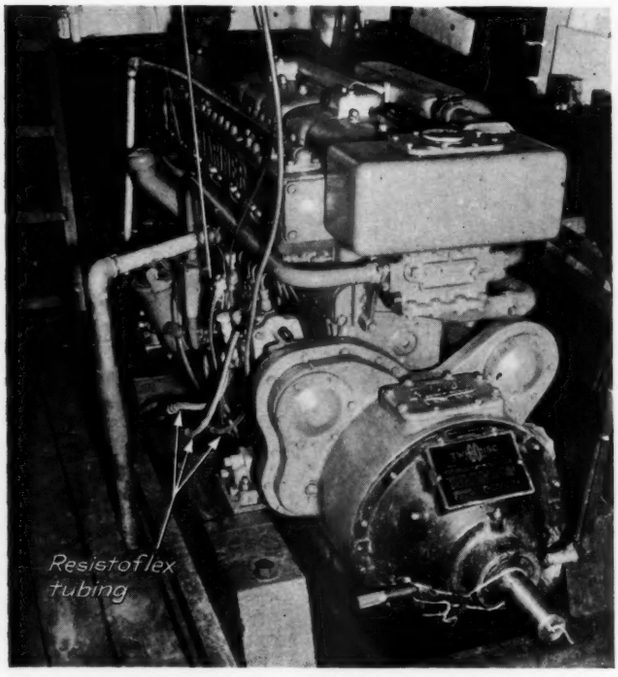
Follow-up device, sometimes added to the cam switch to tie its operation to that of some external device such as a float switch or another cam switch, is a planetary gear mechanism. When change in switch setting is required, auxiliary shaft connected to external device drives an internally cut gear through worm and gear set; direction of rotation is determined by motion of external device. This drives the planetary gear in one direction or the other, rotating the three-land cam on which the planetary gear is mounted. Cam actuates 3-position, single-pole double-throw limit switch which starts the pilot motor in required direction. Central gear, which rotates with the switch main shaft, then rolls the planetary gear and cam back to neutral, at which point the limit switch stops the motor and brings the cam switch to rest at the required position. Follow-up in old switch was differential mechanism.

MODERN DESIGNS – Clutch Hydraulically Dampened

An improvement over the friction plate dampeners previously used, this hydraulically dampened clutch was put into the last of the automobiles made by Willys Overland Company. Two disks are riveted to the center of the splined hub and bear against one end of each of the four coil springs. Center disk of plate assembly bears against other end of each of the four coil springs. Plate assembly is free to rotate on the hub, restrained only by the coil springs. Shock loads are dampened by small hydraulic cylinders mounted inside the coil springs. Plate assembly is filled with heavy oil, sealed with synthetic rubber gaskets. Sudden loads compress springs and force oil out of cylinders into plate assembly. When shock load is released, springs return plate to normal position, and hydraulic cylinders refill. Clutch facings are riveted to stamped spider pieces which in turn are riveted to the plate assembly. Facings are cushioned by spring steel parts riveted to spider stampings. Plate has cushion of 0.030 to 0.040 in. at 1,350 lb. maximum plate load.



Hydraulic Dampener

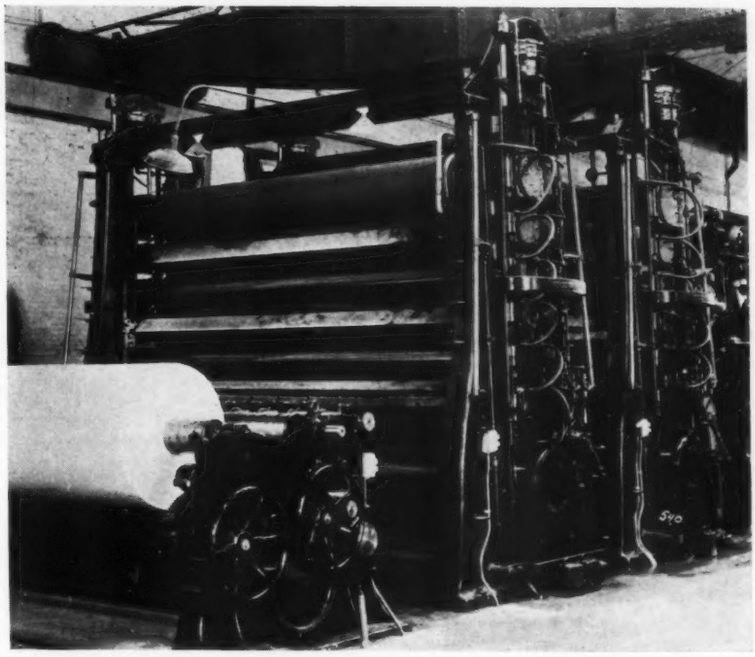


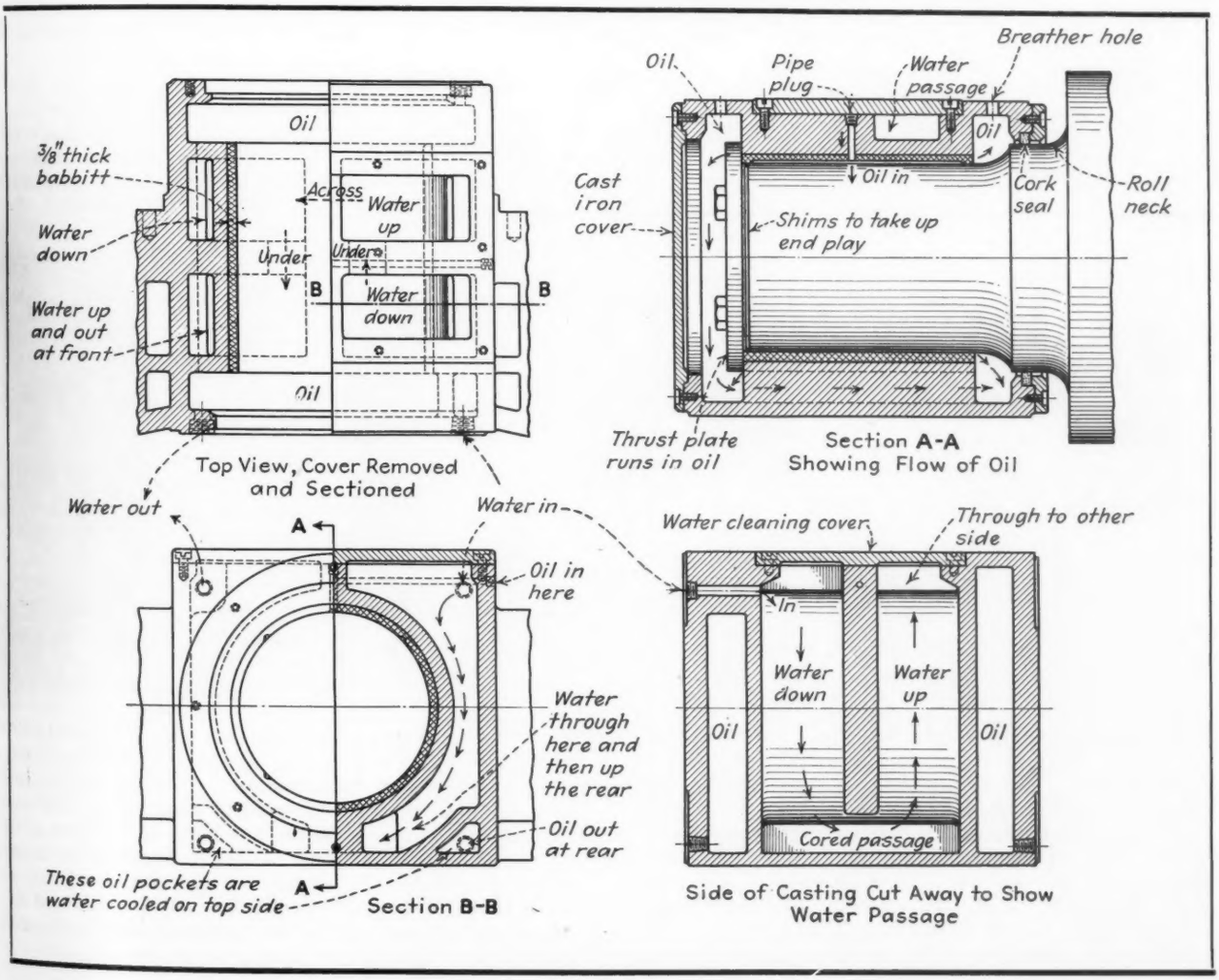
Hose lines on this Mack Mariner diesel engine are now made of polyvinyl alcohol tubing (Resistoflex PVA) in place of rubber or synthetic rubber. The hose, which contains an inner tube of the light, tough and flexible synthetic resin, is inert to hydrocarbons and will not swell or disintegrate in prolonged use. Other applications of the tubing: fuel and hydraulic lines in aircraft, oil feed lines on machine tools, hose lines on paint sprayers, refrigerating machinery.

Aluminum has successfully been replaced in these aircraft seats by laminated plastics. Material is cotton fabric impregnated with phenolic laminating varnish and molded to shape. Weight is less than that of previous aluminum seat. New seat follows closely design of previous seat. Developed by Capac Manufacturing Company, it has passed all Wright field tests. Strength requirements are indicated by the combined weight of pilot and parachute when plane pulls out of 9g dive.

Water and Oil Circulate Through Bearings

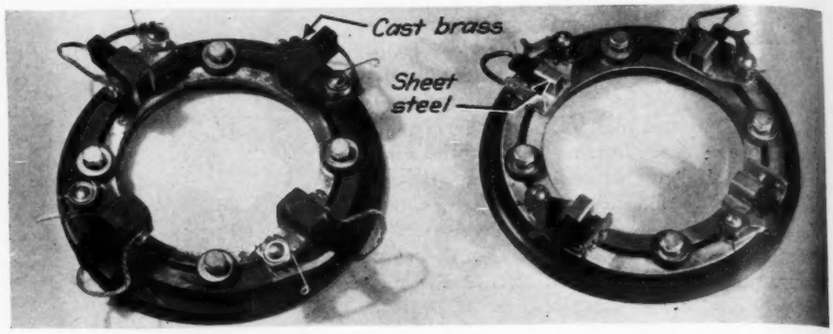
Bearings for these heavy calendering rolls in Rice Barton paper making machinery are cooled by water circulating through passages in cast alloy iron (25 percent steel) housings. Rolls are mounted several high in a calendering unit. Water enters bottom bearing housing and circulates through four successive cored passages around the journal. Water then is carried through neoprene hose from bottom bearing to next higher bearing, cooling it in turn, and so on through all bearings on one side of the unit. Lubricating oil is pressure circulated through all the bearings. It enters bearings through drilled holes leading into top center of the babbitt liner. works its way out to cored chambers at ends of journal. Tube fitted into chamber at rear of bearing then carries oil away from bearing. Oil in chambers and passageways is cooled through metal walls by the cooling water. Only opening between oil and water passages is made in drilling vertical oil hole; this is plugged by ¼-in. standard Allen socket head pipe plug. Oil seal at roll neck is cork ring. Thrust is taken by splash-lubricated disk on end of roll journal. Details of bearing are shown below.

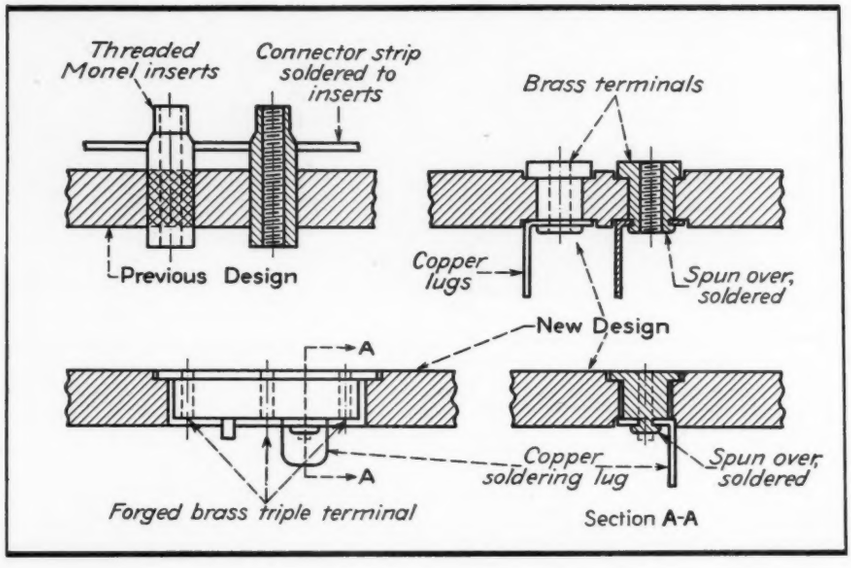




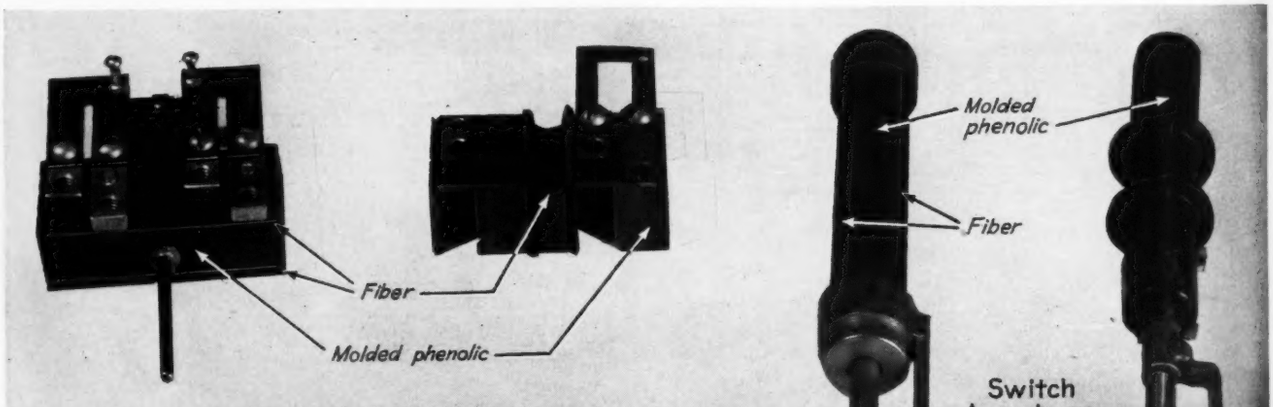
MODERN DESIGNS– Material Saved in Electrical Parts

Generator brush holder assemblies on welders manufactured by Hobart Brothers Company were formerly of cast brass. These are now fabricated from two pieces of heavy sheet steel cut and formed to required shapes and then assembled by spot welding. The base ring, formerly cut from ¼-in. steel plate, is now stamped from ⅛-in. plate. Its diameter is about 9 in. Switch to stamped parts saves several machining operations.



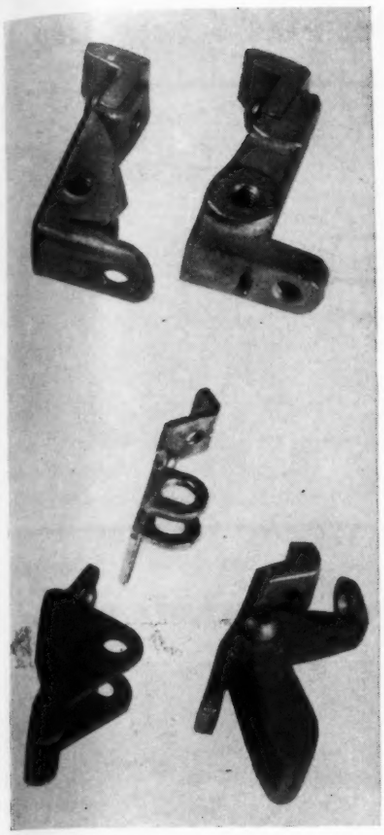


Scrap percentages of phenolic resin terminal strips with 57 molded in inserts was high because of occasional stripped threads or other defects in the inserts. If one insert was defective, the whole strip had to be scrapped. Inserts were monel metal. This cause for scrap was eliminated by molding the piece with no inserts and fastening brass terminal pieces through holes after molding as shown. Defective terminals now can easily be removed. Rearrangement of the terminals also has reduced number of metal parts to 26, with no reduction in number of terminal combinations possible. Spun-over joint between copper soldering lugs and brass terminal piece is soldered. This metal bond is necessary because dimensional instability of plastics makes pressure contact of spun-over joint unreliable for good electrical conductivity.

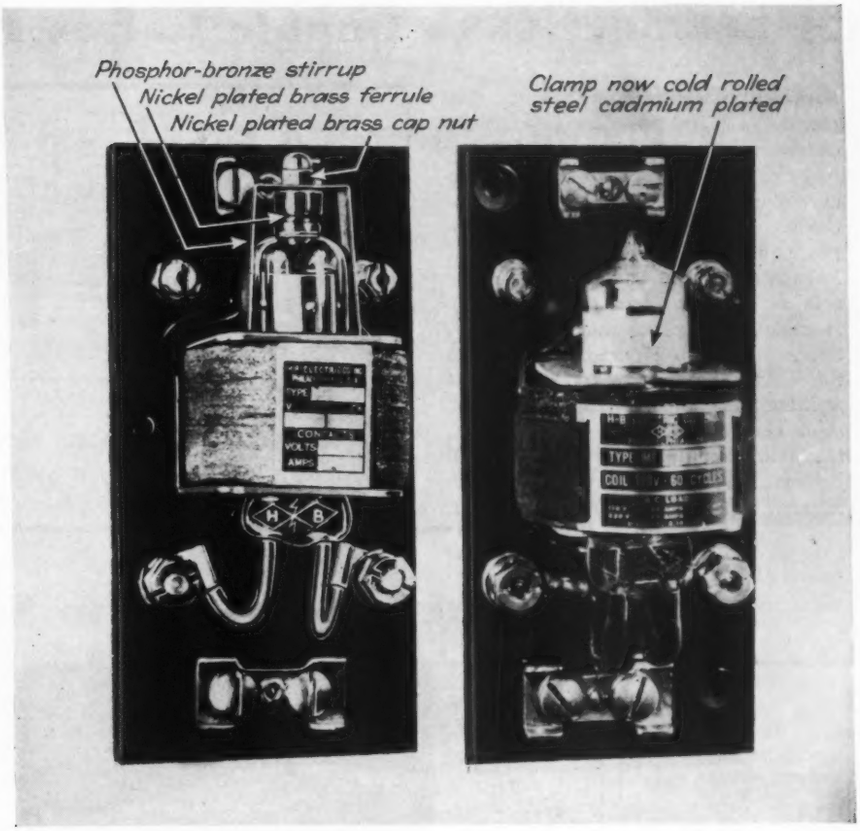


Fibre was formerly used in combination with phenolic resin in this overload trip mechanism to improve electrical characteristics of the surface, but was troublesome from standpoint of shrink, warp, and expansion. Fibre is retained on the redesigned part only as an insert between points of greatest potential difference in a ½-in. groove at the center. These inserts are ⅛-in. thick. The new molded part eliminates milling of 5 slots, drilling of 8 holes, and countersinking 2 holes. Cadmium-plated copper inserts are used as before but are molded in place instead of requiring screws.

Switch armature, upper right, was also a phenolic resin and fibre combination of square cross-section. End caps were steel machined parts pinned to core. The improved design is all molded phenolic of cylindrical cross-section with two circular barrier rings molded in the wall to prevent flashover. Lighter steel ends, which are molded in place, can be made on screw machines whereas the old parts were made on a turret lathe by hand operation. Milling, drilling and turning operations, required on the old armature, were eliminated by the new design. Length of this part is about 8 in.



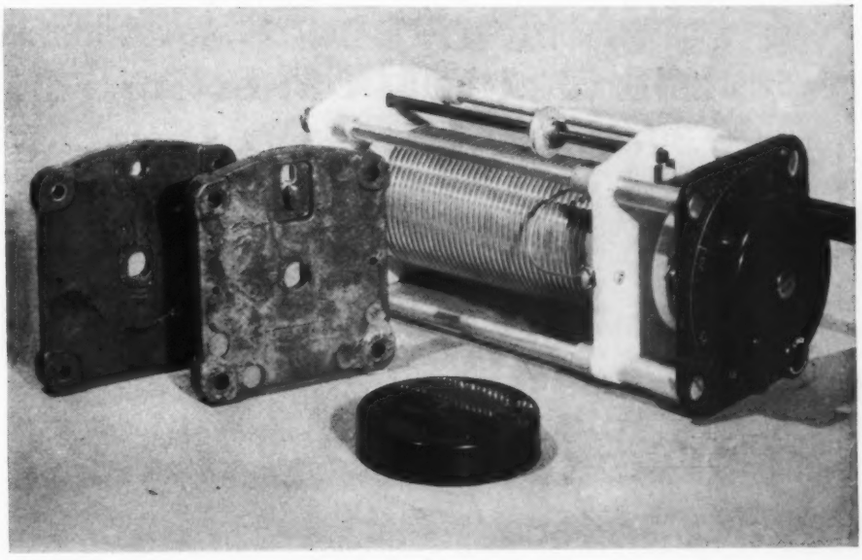
Small cadmium-plated brass castings used in welding equipment by Hobart Brothers have been changed to steel stampings or formed from heavy sheet steel. Brass and steel parts are easily identified in the picture. In part at bottom, two simple formed steel pieces are almost identical with previous cast brass pieces which are shown assembled at lower right.


Phosphor-bronze stirrup
Nickel plated brass ferrule
Nickel plated brass cap nut
Clamp now cold rolled steel cadmium plated

Cap nut and ferrule of H-B silent mercury plunger relay were formerly brass. Stirrup was phosphor bronze. All three parts were nickel plated. Tube mounting clamp in the new improved relay is cold rolled steel, cadmium plated. Elimination of brass and bronze parts released strategic metals and an automatic screw machine for other important war work. Adjusting screw on the clamp is a standard part, not requiring special screw machine work. New mounting clamp holds the mercury tube so as to give twice the stability of previous design. Top terminals were made more accessible, thereby reducing danger of tube breakage and simplifying installation. The relay, which has only one moving part, is rated at 30 amp., 110 volts, 1 hp.

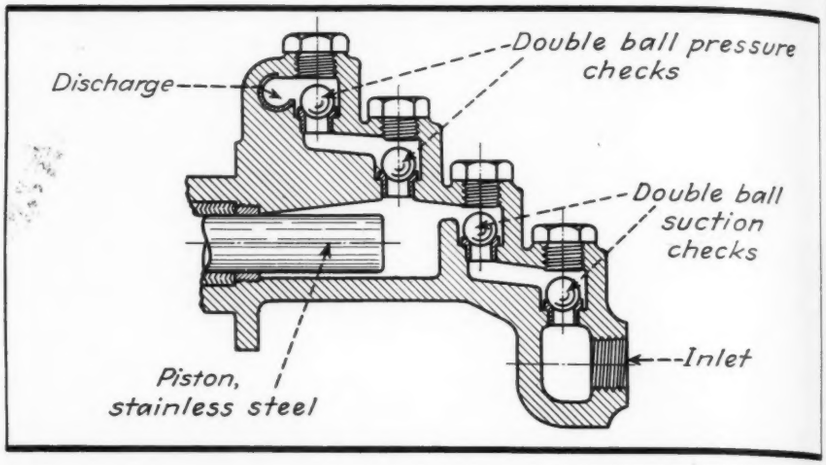
Mycalex Replaces Ceramic, Tolerances Improved

Two difficult-to-obtain materials, molded steatite ceramic and 17ST aluminum, have been conserved in redesign of four parts in this rotary inductor for radio transmitters. Mycalex, a mica and glass-filled molded plastic, permanently replaces steatite in the two coil ends, giving advantages of closer tolerances and 50 percent higher strength. In these as in many parts combining electrical and mechanical functions, close dimensional tolerances makes molding of ceramic a difficult and expensive job. Front of inductor formerly was machined from 17ST aluminum sheet hollowed out for light weight. Now it is die-cast of aluminum alloy (88 percent aluminum, 12 percent silicon). Gear housing on dial formerly was turned down from 17ST bar stock, now is rag-filled molded phenolic.

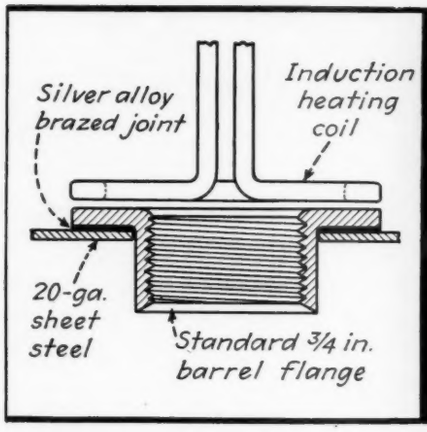


MODERN DESIGNS – Double Valves Prevent Clogging

Step valve system, with double ball checks in both the suction and discharge sides was designed by Milton Roy Pumps to insure volumetric accuracy of this apportioning pump even though dirt particles should prevent proper seating of one of the ball checks. In such cases the second ball in the line acts as the check and the obstruction is cleared away on the next stroke. Since the pump is used primarily in the chemical industries it is made of stainless steel. Exact type of stainless steel chosen depends upon chemicals the pump handles. Piston can be adjusted from 0 to 100 percent capacity. Maximum pressure 20,000 lb. per sq.in.

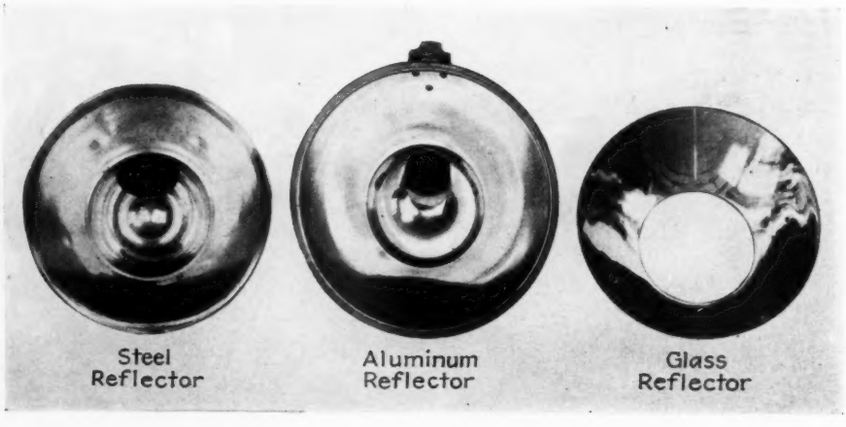


Flange Induction-Brazed to Steel Container



Induction brazing made possible this design of clean, air-tight joint between filling flange and 20-ga. sheet steel container. Brazing was done on Thermonic induction heating equipment after container and fins had been assembled by seam welding. Two rings of silver brazing alloy were preplaced around standard 3/4-in. barrel flange, flux was wiped on, and flange was inserted. Water-cooled heating coil, positioned as shown in sketch, heated the flange and a small area of sheet steel to 1,400 deg. F. with no danger of burning the sheet metal. Pressure was applied through center of coil. Strength of brazed joint is as high or higher than that of original metal.

Silvered Glass Substituted in Reflectors



Silvered glass reflectors are now taking the place of aluminum reflectors in industrial and commercial luminaires. For comparison, the reflection factor of the Alzak aluminum reflector is 80–82 percent and the silvered glass reflection factor is 86–90 percent. Various types of glass are used. Two of the most common are the lime crystal fire polished and the blown glass. The silvered glass reflectors are coated with chemically deposited pure silver, plus electrolytically deposited pure silver, plus electrolytically deposited pure copper for greater efficiency, plus a baked metallic coat.

STRENGTH OF PLASTICS

Structural Data for Thermosetting Compounds

H. R. MOYER
Westinghouse Electric & Manufacturing Company

Safe data on tensile, compressive, flexural, impact, shear and bond strengths, and accurate information on effects of temperature and stress-strain characteristics are necessary in the preliminary determination of minimum sections for structural plastic parts. This article presents these much-needed physical data for eight commonly used high-strength phenolic materials—four laminated and four molded—in quick-reference charts. Particularly valuable are the data comparing strengths in different directions of laminated phenolic resins. Limitations: these data apply specifically to only eight out of the countless plastic materials available.

HIGH-STRENGTH thermosetting plastics consist generally of a synthetic binder such as the phenol-formaldehyde resins, and a filler of laminated, macerated, or comminuted form. The resin-impregnated filler is compressed under heat and pressure into a permanently solid substance with high structural strength and good dielectric properties. Although the forming operation is actually a molding process, a distinction is commonly recognized between the standard and special molded shapes.

Plate, rod, tube, angles, and channels are all standard shapes. These forms are most commonly made of laminated plastic consisting of layers of impregnated paper or cloth bonded under pressure. The standard shapes are formed in relatively simple molds conforming to the desired shape. For sheets, only flat plates or platens, top and bottom, are necessary; layers of impregnated filler are stacked between the platens of the press, and heat and pressure are applied.

In the special molded shapes macerated or comminuted types of plastic materials are formed in compression type molds. Macerated fillers include chopped paper, chopped or shredded fabric, and various other types of fibres of reasonable size and form. Comminuted fillers are pulverized or finer cut fibres such as common wood flour.

In many plastic parts where certain directional strength properties are required, special shapes can be molded with laminated or a combination of laminated and macerated structures. The laminated fillers reinforce those sections of a molded shape where higher strength than is obtainable with all-macerated plastics is required.

The favorable strength-weight ratio of plastics is the principal reason for their use in place of steel, aluminum and wood. Table I compares the physical properties of four types of laminated plastics with alloy steel, aluminum, magnesium, and wood. As the table shows, the tensile strength-weight ratios of the laminated materials range from one-third to one-half as high as those of the metals. The compressive strength-weight ratios of the laminated plastics are better than those of other materials.

The four types of laminated and the four types of molded materials covered in this article have been given arbitrary grade numbers in the charts and in Table I. For specifications and descriptions of these types, see Table II. All of these compounds are available from many laminators or suppliers of molding compounds, although materials upon which tests were made for data in this article were all produced by Westinghouse Electric & Manufacturing Company.

Figs. 1 and 2 show the effect of temperature on the tensile, compressive, and impact strength of laminated Type 2, the heavy-weave canvas base laminated plastic. Although only one type is covered in these charts, the same general effects might be expected in the other grades.

Fig. 3 gives an easy-to-read comparison of the strength of the four types of

Table I—Comparison of High-Strength Plastics, Woods and Metals

Type of Material	Specific Gravity	Tensile Strength, lb. per sq. in.	Ratio of Tensile Strength to Sp. Gr., lb. per sq. in.	Compressive Strength, lb. per sq. in.	Ratio of Compressive Strength to Sp. Gr., lb. per sq. in	Modulus of Elasticity in Tension (E_t), lb. per sq. in.	Ratio of E_t to Sp. Gr., lb. per sq. in.	Modulus of Elasticity in Compression (E_c), lb. per sq. in.	Ratio of E_c to Sp. Gr., lb. per sq. in.
Laminated 1	1.35	12,500	9,250	35,000	25,900	1.0×10^6	7.5×10^5	0.61×10^6	4.5×10^5
Laminated 2	1.35	11,000	8,000	35,000	25,400	1.05×10^6	7.6×10^5	0.56×10^6	4.1×10^5
Laminated 3	1.35	11,000	8,150	31,000	23,000	1.05×10^6	7.8×10^5	0.6×10^6	4.5×10^5
Laminated 4	1.35	16,000	11,800	38,000	28,100	1.7×10^6	13×10^5	0.83×10^6	6.2×10^5
Stainless Steel (18–8)	7.85	185,000	23,600	150,000 (a)	19,100	30×10^6	38×10^5	30×10^6	38×10^5
Chrome Molybdenum Steel (Heat-Treated)	7.85	180,000	22,900	150,000 (a)	19,100	29×10^6	37×10^5	29×10^6	37×10^5
Aluminum Alloy (24ST)	2.80	62,000	22,100	40,000 (a)	14,300	10.4×10^6	37×10^5	10.4×10^6	37×10^5
Magnesium Alloy (AM-585)	1.81	46,000	25,400	35,000 (b)	19,300	6.5×10^6	36×10^5	6.5×10^6	36×10^5
Aircraft Spruce (Douglas Fir)	0.43	10,000	23,300	5,000	11,600	1.3×10^6	30×10^5	1.3×10^6	30×10^5
Birch Plywood	0.80	13,100	16,400	5,700	7,100	1.4×10^6	18×10^5		

(a) Yield point in compression (b) Yield point in tension

Table II—Specifications of High-Strength Plastics

Designation on Charts	Specifications			Type and Characteristics	Principal Uses
	Army	Navy	N.E.M.A.		
Laminated 1	HH-P256 or 71–484 Type II Grade LE	17-P-5 Type FBG	Grade LE	Fine weave fabric base. High moisture resistance, tough, good machinability, good dielectric strength	Structural and mechanical parts where higher strength than paper-base is required.
Laminated 2	HH-P256 or 71–484, Type II Grade C	17-P-5 Type FBM	Grade C	Heavy-weave canvas base. High strength, high impact, tough, easy to machine.	General purpose for mechanical parts. Widely used in gears. Not recommended for electrical uses.
Laminated 3	HH-P256 or 71–484, Type I, Grade XX	17-P-5 Type PBG	Grade XX	Cotton fibre paper base. Good electrical and mechanical properties. Can be drilled, tapped and machined.	Structural and mechanical parts in fairly humid conditions. Avoid excessive splitting stresses.
Laminated 4	HH-P256 or 71–484, Type I, Grade X	17-P-5 Type PBM	Grade X	Kraft paper base. High strength, good electrical properties, low cost. Machinable.	Structural and mechanical parts not subject to high humidity or excessive impact. Simple machined and other mechanical parts with medium stresses.
Molded 1	—	Type CFI	—	Chopped fabric base. High impact strength, good mechanical properties.	High-strength general purpose molded parts.
Molded 2	—	—	—	Chopped (coarse to medium) fabric base. Good mechanical properties.	General purpose; recommended for pulleys, etc. Not recommended for severe electrical applications.
Molded 3	—	—	—	Chopped fine fabric; readily moldable; high moisture resistance.	Suitable for intricate molded designs; chemical resistance. Not good under severe impact.
Molded 4	—	—	—	Chopped heavy fabric base.	General purpose molding compound for electrical and mechanical uses. Not recommended for severe electrical applications, nor for intricate designs.

Fig. 1—Thermal Effects on Tension, Compression

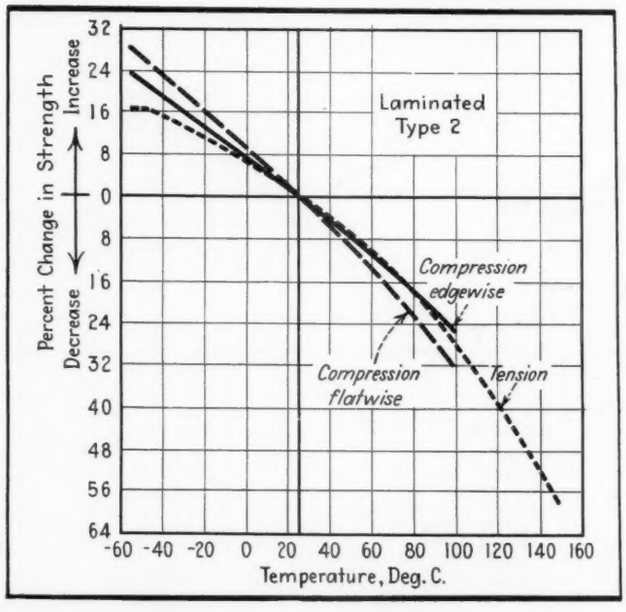
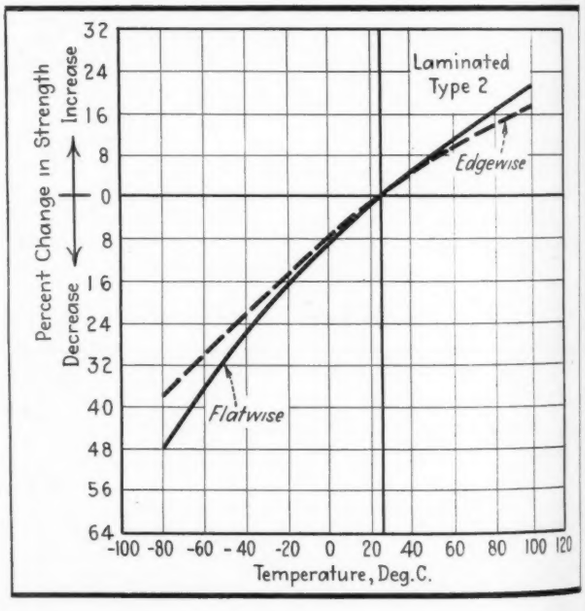


Fig. 2—Thermal Effects on Impact



laminated plastics. There is a definite directional strength effect in laminated plastics, as shown on these strength charts. The term "with the grain" corresponds to the A.S.T.M. definition of "lengthwise," meaning in the direction of the continuous or longest length of the cloth or paper from which the laminated plastic sheet is made.

Similar graphic strength charts in Fig. 4 cover the four types of macerated cotton fabric generally used in high strength molding compounds. Directional strength characteristics are not as marked in these macerated materials as they are in the laminated plastics. However, the molding compounds are not entirely homogeneous in structure and strength. The values given in the charts are in the direction of greatest strength.

Fig. 3—Strengths of Laminated Plastics

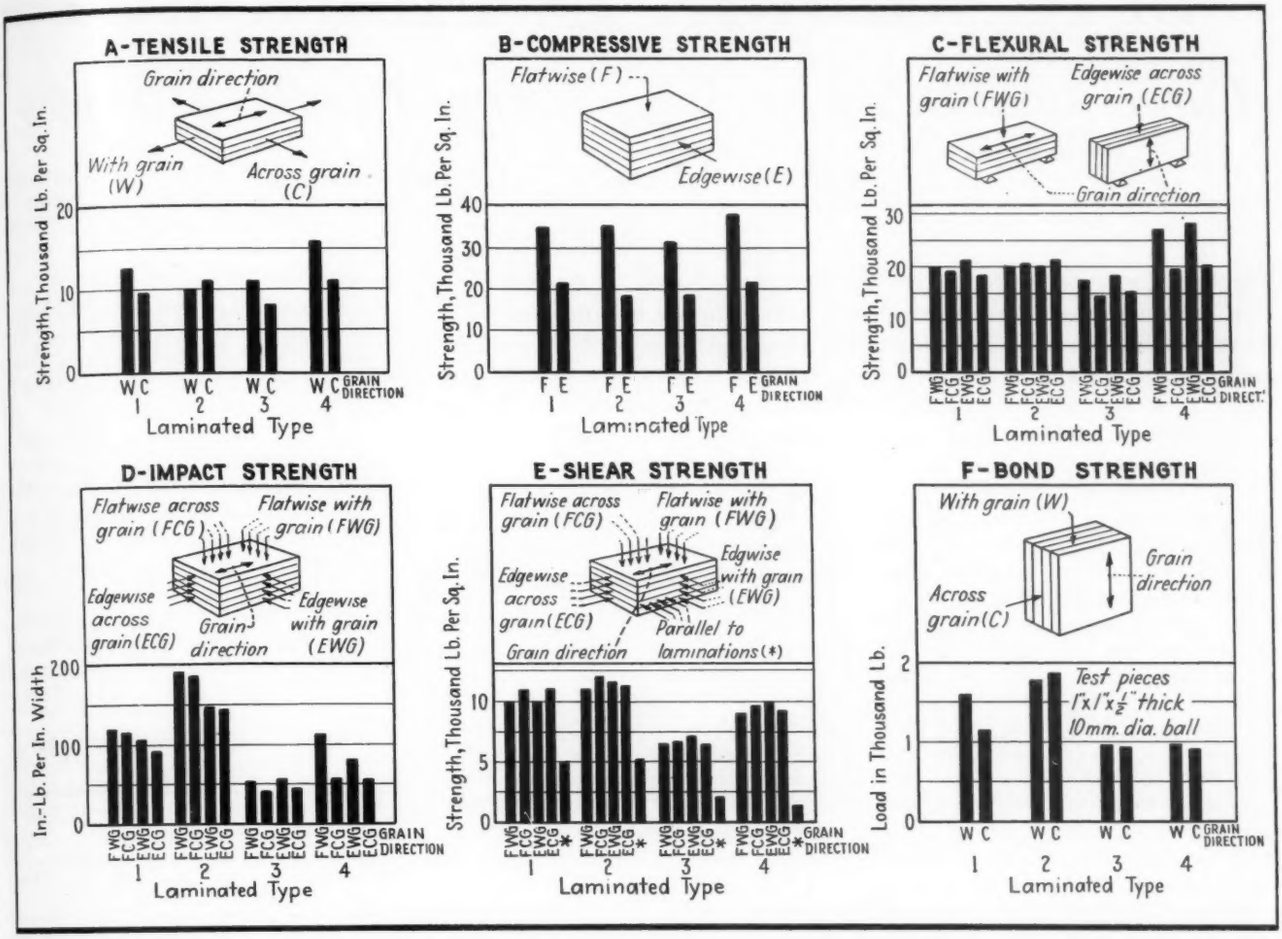
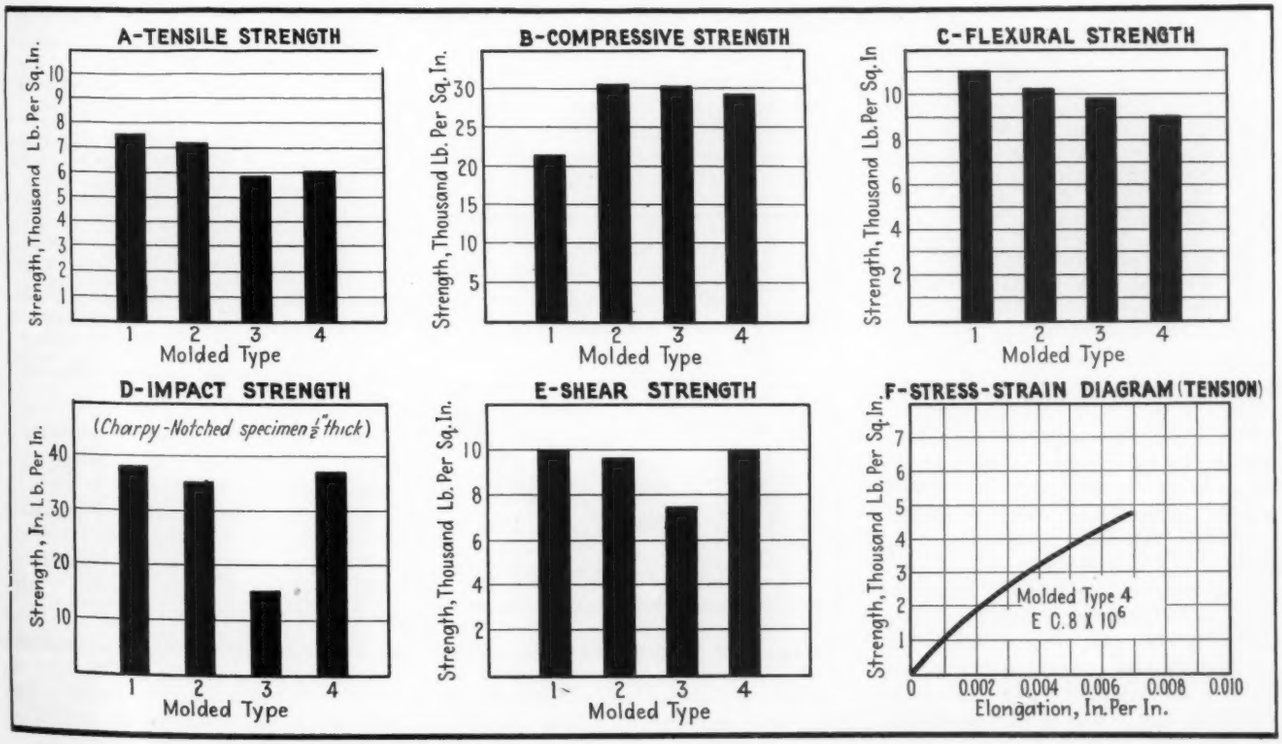


Fig. 4—Strengths of Molded Phenolic Plastics



SPRINGBACK IN FLANGING

Curves and Table for Determining Die-Block Angles

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The test conditions under which the data were obtained are described briefly. Curves give the values of a constant *K* for different ratios of sheet thickness to bend radius, and by using the value of *K* in a simple formula, the springback is calculated. The authors also present a table which gives directly the angle of springback in forming 90 deg. flanges in six different thicknesses of sheets of aluminum in the harder tempers.

PRESENT-DAY practice in aircraft production tends more and more toward the forming of sheet metal parts from materials in the harder tempers. In particular, 24S Alclad (4.5 Cu, 0.6 Mn, 1.5 Mg, balance Al) is now formed in the heat-treated (ST) condition wherever possible, instead of following the older custom of forming it in the annealed (SO) condition and then heat-treating it to achieve the necessary strength and corrosion resistance. While heat-treatment in itself offers no particular problem, it is an expensive and time-consuming operation when applied to formed parts. It often necessitates reworking a part in order to remove distortion caused by quenching.

In forming parts out of sheets in the harder tempers, however, several special problems are encountered, one of the most important of which is that of "springback," which is much more pronounced than in the forming of sheets that are softer or annealed. Springback is the amount to which a formed part returns toward the original flat shape of the sheet when the forces applied to deform it have been removed.

For example, when making straight flanges, the angle of springback is the difference between the flange angle after the part has been removed from the die and the block angle, that is, the angle to which the sheet was bent on the form block. Springback is caused by the elasticity remaining in the material even though it has been given some plastic deformation by the applied forces in the forming operation. In forming material which has a high yield stress, such as 24ST, the amount of springback is quite pronounced, particularly when the forming is done by the Guerin process, that is, by simple bending in a single-acting press with rubber punch. For such work, the springback must be allowed for in the design of form blocks. Annealed materials springback but the amount is much less and can readily be compensated by undercutting the form blocks 2 or 3 deg., which is standard for forming soft aluminum.

In view of the desirability of forming as many parts in the ST condition as possible, an investigation was undertaken by the Production Research group of the Lockheed Aircraft Corporation to determine the springback of straight flanges in 24ST Alclad material.

Initial attempts at constructing springback tables for hydro-press forming were based on values compiled by inspectors and form-block makers. It was soon discovered that different groups of data did not agree. This led to the realization that the amount of springback varies materially with operating conditions on the hydro-press such as (1) condition and hardness of the rubber pad, (2) amount of friction between the rubber and the part formed, (3) pressure exerted by the hydro-press, (4) contour of the part, (5) height of the form block, and 6) pressure-boosting effect resulting from the proximity of other objects on the hydro-press platen. Investigation revealed that each of these factors has, under certain conditions, an appreciable effect. Detailed study of these variables is beyond the scope of this article but their probable effect under a normal range of variation in press operating conditions will be taken into account in presenting tables of springback data and assigning limits of accuracy thereto. By taking data from a series of experimental tests, it has been possible to construct the tables and curves presented herein, which may be used to predict springback angles in straight flanges to within approximately plus or minus 2 deg. It should be emphasized that these tables and curves apply only to flanges that are straight.

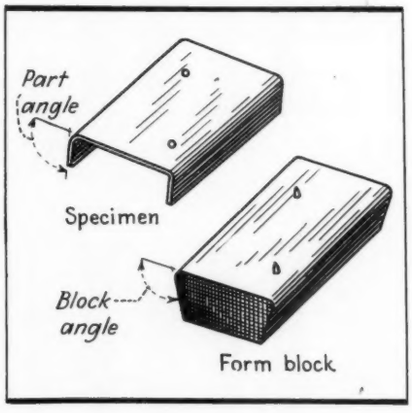

Fig. 1—Type of specimen and form block used in the tests from which were obtained the data on which Table II and the curves are based

Table I—Conditions During Springback Tests

Material	24S-T Alclad Aluminum Alloy
Material Thicknesses	0.020 in., 0.032 in., 0.040 in., 0.064 in.
Bend Radii	Full range from $\frac{1}{32}$ in. to $\frac{1}{2}$ in. in increments of $\frac{1}{32}$ in.
Block Angles	530 bends on block with 98 deg. angle; 340 bends on blocks having angles of 50 deg., 60 deg., 70 deg., 75 deg., 80 deg., 105 deg., 115 deg., and 130 deg.
Rubber in Press	A 5-in. pad of rubber was used for all tests. Most of the specimens were run with rubber having a Shore hardness of 60–65. A few were run with rubber having a Shore hardness of 70–72.
Pressure	The press was operated at an average pressure of 1,250–1,350 lb. per sq. in.

Using specimens of the type illustrated in Fig. 1, an extensive series of tests were run on the hydro-press using different combinations of material thick-

ness, block radius and block angle. Springback measurements were recorded for every part tested. The tests were run under production conditions, allowing what might be termed a normal range of variation in the operating factors already described. Table I gives a general outline of the test conditions.

In order to avoid the necessity of presenting a large family of curves representing different combinations of thicknesses, radii and similar factors, the data accumulated from the above tests was plotted in "dimensionless" form using t/R as the basic variable (as shown in Fig. 2), R representing the radius of the form block, and t the thickness of the material. With various values of t/R as the independent variable, the abscissa, and K as the ordinate, the curves in Fig. 2 were plotted. The values of K were calculated from the formula:

$$K = \frac{\text{Part Angle}}{\text{Block Angle}}$$

$$= \frac{\text{Block Angle} - \text{Springback Angle}}{\text{Block Angle}}$$

It was originally intended to present separate groups of data and curves, each group representing a specified set of conditions under which the experiments were carried out. It was found, however, that owing to the complexity of the variables involved, the values in any one group overlapped those of the other groups to such an extent that segregation and identification of the individual groups was impossible. Therefore, all of the data were combined into one group and plotted in the form shown in Fig. 2. Practically all of the points fell within the region bounded by the dotted lines. This region obviously defines a curve, the general shape of which is given by the solid line of Fig. 2, representing the mean of the values plotted.

For practical purposes the solid curve of Fig. 2 can be used to determine springback to an accuracy of plus or minus 2 deg., assuming that production conditions are similar to those described in Table I. As a convenience in determining springback angle for parts of thicknesses and bend radii in common use, Table II gives values obtained from the solid, mean curve, of Fig. 2 for commonly used thicknesses of material.

The use of Fig. 2 to find part angle from known form block dimensions is simple and straightforward, since the variable R represents block radius and the part angle will be equal to K times block angle. If, however, it is desired to determine the form block dimensions required to produce a given part angle and part radius, an approximation has to be made by adopting the assumption that R equals block radius which equals, or nearly so, the part radius. This is very nearly true for sharp bends such as are usually encountered in dealing with flanges. It is not true for shallow contoured parts having large radii of curvature. Fig. 2 should not be used for such parts.

Table II—Springback Angles for 90 Deg. Straight Flanges in 24S-T Alclad Sheet

(Accuracy—plus or minus 2 deg. for production conditions similar to those set forth in Table I)

Part or Block Radius*	Springback Angle in Degrees					
	0.020 in. Material	0.025 in. Material	0.032 in. Material	0.040 in. Material	0.051 in. Material	0.064 in. Material
1/32	7¼	7				
1/16	9½	8½	7¾			
3/32	11¼	10	9	8¼	7½	
1/8	13½	11½	10	9¼	8½	
5/32	16	13½	11½	10¼	9	7½
3/16	18¼	15½	12¾	11	9¾	9
7/32	21	17½	14½	12¼	10½	9¾
1/4	23¼	23½	16	13½	11¼	10
9/32	26	26	17½	14¾	12¼	11
5/16	28¼	28¼	19	16	13	11½
11/32	30¾	30½	20½	17	14	12
3/8	33	33	22	18¼	15	12¾
13/32			23¾	19½	16	13½
7/16				21	16¾	14¼
15/32						15
1/2						16

* Assumed approximately equal for bends of this nature.

For part angles other than 90 deg., multiply springback angle by the following factors:

Part Angle	*Factor*	*Part Angle*	*Factor*
50	0.555	75	0.835
55	0.611	80	0.890
60	0.667	85	0.945
65	0.722	95	1.056
70	0.779	100	1.110

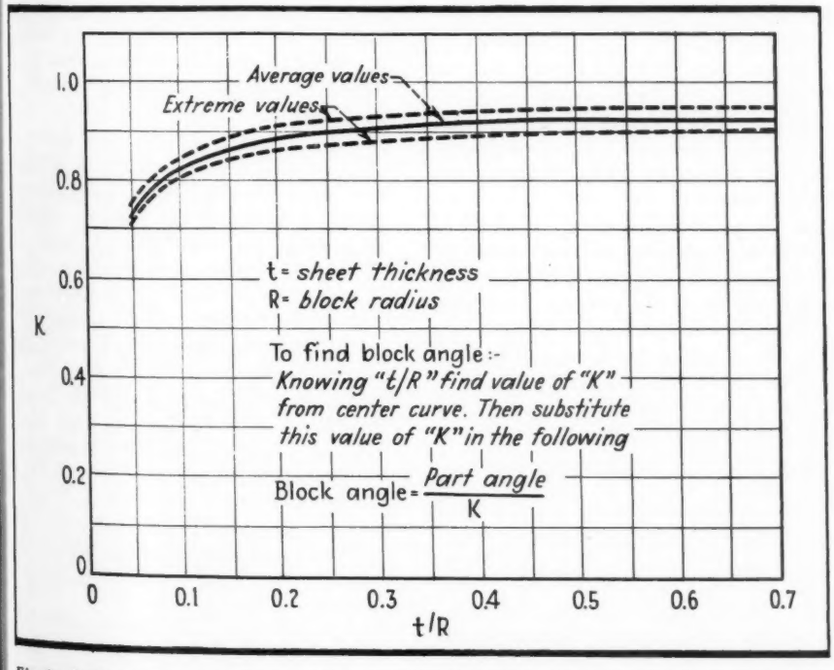

Fig. 2—Springback curves from which to determine the block angle for 90 deg. straight flanges in 24S-T Alclad

SLEEVE BEARINGS – III

Factors That Govern Their Design and Performance

BRUNO SACHS
Technical Director, Johnson Bronze Company

Continuing the series of articles that began in the May number, followed by Part II in the June number of *P. E.*, this third installment deals with factors such as the effects of temperature and oil corrosion on the properties of tin base babbitts, lead base babbitts and copper-tin-lead alloys when used as bearing materials. The importance of good bonding technique is also emphasized. The field, properties and characteristics of self-lubricating bearings are also set forth. The requirements necessary for perfect backing of the bearing by its housing are analyzed. A description of the various types of oil grooves and their function in sleeve bearings for general purpose applications is also included in this part of the article.

PERMISSIBLE PRESSURE on a sleeve bearing in most applications can be determined by the thermodynamical considerations that limit the bearing temperature (see Equation (2a) and Figs. 2 and 3, May *P.E.*). Another possible limitation of the permissible pressure might come from the requirements as to oil film thickness (see Figs. 7, May *P.E.*, and Reference Book Sheets, June *P.E.*) in order to obtain the necessary $\sqrt{Zn/p}$ with available oils. Still another limitation for the permissible pressure might come from the requirements as to wear and seizure.

In comparatively few, but important applications (for instance, connecting rod bearings of high speed combustion engines) will the strength of the bearing material be the limiting factor for the bearing pressure; these cases do exist especially with babbitts and high lead bronzes.

Safe pressures for static loads are given in Table II (see June *P.E.*) on the basis of material strength and strain.

When loads are dynamic the fatigue resistance of the material at the working temperature is authoritative for the permissible pressure.

Each type of machine, of course, has a characteristic load cycle peculiar to itself. Even within one category of machines the intensity of the loads and their manner of changing as well as the design may differ so widely that one and the same material will safely resist the loads applied with different permissible fatigue stresses.

Adequate values for the permissible pressure from the point of view of fatigue resistance are 20 to 40 percent below the given values for static load. In heavy shock applications reductions up to 50 percent might be advisable.

The sharp decreases of strength of the babbitts with rising temperatures should be noted (see Table II, June *P.E.*). Attention is here called to the fact that one constituent of the babbitt structures starts to melt at 445 deg. F. In leaded bronzes, lead melts at 620 deg. F., and lead sweat starts even at lower temperatures. Safe working temperatures of a bearing from the point of view of material must be at least 150 to 200 deg. F. below these destructive temperatures.

Tin and lead babbitts present no particular problems because of corrosion caused by the acids and oxidation products of commercial oils; however, it appears that tin babbitts are superior in this respect.

In copper-tin-lead alloys, the lead is distributed in the copper-tin matrix in the form of almost pure lead. Pure lead is susceptible to oil corrosion. Addition of tin and antimony to lead will prevent lead corrosion in babbitts, but not in copper base alloys, because with bronzes these additions go into solid solution with the copper during solidification, leaving the lead pools almost unalloyed.

This oil corrosion of the lead becomes more serious when the lead content is high and the tin content is low. High lead bronzes, therefore, require specially compounded "prescription" oils. Generally speaking, oil corrosion increases as the oil and bearing temperatures increase.

The critical situation which exists today as to the strategic tin supplies and, as a consequence, the possibility of a heavily restricted use of tin brings into the foreground the question of the substitution of lead base babbitts for tin base babbitts.

From the data presented in Table II (see June *P.E.*) and from what was previously stated, it follows that tin base babbitts are superior to lead base babbitts in all characteristics essential for a bearing material except, theoretically, in the anti-disturbance value which is a little lower for lead base babbitts. This, however, does not mean that lead base babbitts cannot be used in most applications instead of tin base babbitts.

The main disadvantages of lead base babbitts are their lower strength at elevated temperatures (see Table II, June *P.E.*) and their inferior thermal properties, that is, specific heat and heat conductivity.

As was pointed out in Part I of this article (May *P.E.*) the stationary bearing temperature is determined mainly by the friction heat produced, by the size of the housing, the conditions of the surrounding air and also by the quantities of liquid coolant. The specific heat and the heat conductivity of the bearing material do not enter into the picture for the average stationary bearing temperature.

This, however, is not true for the local temperature rises caused by outside disturbances or by dynamically changing loads. It has been previously mentioned that with violently increasing and changing load pressures (within one period of the load cycle) the limit of fluid friction might be reached or exceeded momentarily on minute contacting zones, thus resulting in semi-fluid friction states (although the bearing "as a whole" runs with fluid friction) and in local rises of temperature far above the average bearing temperature.

The amount of these local temperature rises caused by disturbances under similar conditions is proportional to the expression

$$\frac{1}{gS}(1-\lambda) \qquad (4)$$

wherein

g = specific gravity of the bearing material

S = specific heat of the bearing material
λ = linear heat conductivity of the bearing material

In Table III are shown values of these constants and values of the Expression (A) for tin and lead base babbitts. From the table it can be seen that the value of (A) is 45 percent higher for lead base babbitt than for tin base babbitt.

In other words this means that identical disturbances will cause with lead base babbitt a 45 percent higher local temperature rise expressed in degrees Centigrade (equivalent to approximately 38 percent temperature rise expressed in degree Fahrenheit) than with tin base babbitts.

Failures in main and connecting rod bearings because of fatigue, occur occasionally even with tin base babbitts and originate in, and start from, these places of local temperature increase. This danger is accentuated with lead base babbitts. Effective measures which will offset this behavior are to intensify the cooling of the bearing and to decrease the lining thickness.

The slightly inferior wear and corrosion properties, as well as the lower strength at elevated temperature and the thermal properties of lead base babbitts, might have some reflection on the life of a bearing. This is a disadvantage, which can and will have to be compensated for by additional care in design and maintenance.

Furthermore, the lead-arsenic-antimony babbitts containing tin in small amounts up to one percent might find a wider use. These babbitts do not lose their strength at elevated temperatures as much as do the lead-tin-antimony babbitts. It is also probable that driven by the force of necessity other types of lead base babbitts will be improved and used. Under normal conditions, when supplies of tin on hand were sufficient, incentive was lacking to develop non-tin bearing compositions.

Important factors which should be considered when employing bimetallic bearings are the quality and the strength of the bond between lining and backing material Good bonding technique results in a metallurgically alloyed intermediate layer along the entire surface. A poor bond strength or the presence of small spots which are not alloyed decrease the life of the bearing; this is especially evident under changing load.

Decreasing the thickness of the lining improves fatigue resistance in a good bonded bimetallic bearing, but decreases conformability, because the supporting influence of the stronger backing material becomes more prominent. The thinnest lining used today is 0.005 in.; it is most appropriate when the load stresses are close to the lining material's fatigue strength, but it requires a more closely controlled clearance, surface finish and shaft deflection than a thicker lining; also adequate provisions for oil filtration, because foreign particles in the oil are more detrimental with thin linings. The thinner the lining, the more attention must be paid to the quality of the surface to which the lining material is bonded, because rough tool marks would act as notches detrimental to the fatigue resistance of the thin lining. This means breaking with the traditional practice of roughing the surface in order to get increased surface for the bond. Improved and strictly controlled bonding techniques should be used.

A special and interesting place in the bearing field is occupied by the porous "self-lubricating" bronze bearings. (For further reference see "Porous Metal Bearings, Methods of Design and Discussion of Properties." *P.E.*, Sept., 1941). This type of bearing was originally intended and developed for minor and light applications where regular lubrication could not be provided because of an inaccessible location or because of the nature of the equipment such as household appliances and textile machines; long time lubrication being provided by an oil supply obtained by impregnating the porous bushing with a suitable lubricant.

The practical application of this idea has surpassed all expectations and porous bronze powder bushings are now being regularly used as a standard in this class of work and equipment.

In the process of manufacturing powdered metal bearings, predetermined amounts of the prepared powder mixture are fed into the cavities of special precision dies mounted in automatic double acting presses. The powder is then compressed into briquettes under pressures varying from 30,000 to 50,000 lb. per sq. in. depending upon the size of the bushings and the desired strength and porosity. The porosity is also controlled by added predetermined amounts of volatile salts in the powder mixture, which are eliminated in a sintering operation in which the compressed briquettes travel through electrically heated conveyor furnaces. A closely controlled reducing atmosphere is maintained in the furnace. After the sintering operation the briquettes are then cooled in a reducing atmosphere.

Diffusion and sintering of the metallic clean powder particles result in a strong bushing structure, accompanied by slight changes in dimensions. The finished size of the bushing is obtained by an operation on double action presses that size the outside and inside diameters, the wall thickness and the length. The progress made in manufacturing technique as to control of prealloyed powder, porosity, tolerance of dimensions and strength of the finished product, opens a wide field of new and more severe applications as a substitute for babbitt and solid bronze bearings which because of their method of lubrication run in the state of semi-fluid or mixed friction.

By providing a regular lubrication system and an oil supply which is periodically supplemented and replaced, as is ordinarily done in usual lubrication practice, porous powder bearings offer several worthwhile advantages: (a) they are comparatively inexpensive; (b) they do not require oil grooves, the uniform distribution of the oil over the whole bearing area is secured by the capillary action of the porous structure; (c) running-in and conformability properties, expressed in the plastical, elastical and total anti-disturbance values are good and their strength is adequate (see Table II, June *P.E.*); (d) they can be manufactured to close tolerances and their surface roughness is favorable, average profilometer reading is 20 micro-inches.

Any machining should be avoided because it closes the exits of the pores on the surface of the compressed material, therefore, if these bearings have to be "machined" in assembly, this must be done by sizing or burnishing operations.

When these bearings are pressed into a housing, a certain amount of close-in

Table III—Thermal Properties Of Babbitts

	Tin base babbitt	Lead base babbitt
g, specific gravity, grams per cu. cm.	7.3	10.7
S, specific heat, calories per gram	0.06	0.03
λ, linear heat conductivity, calories per cm. per sec. per deg. C.	0.11	0.055
$\frac{1}{gS}(1-\lambda)$	2.03	2.95

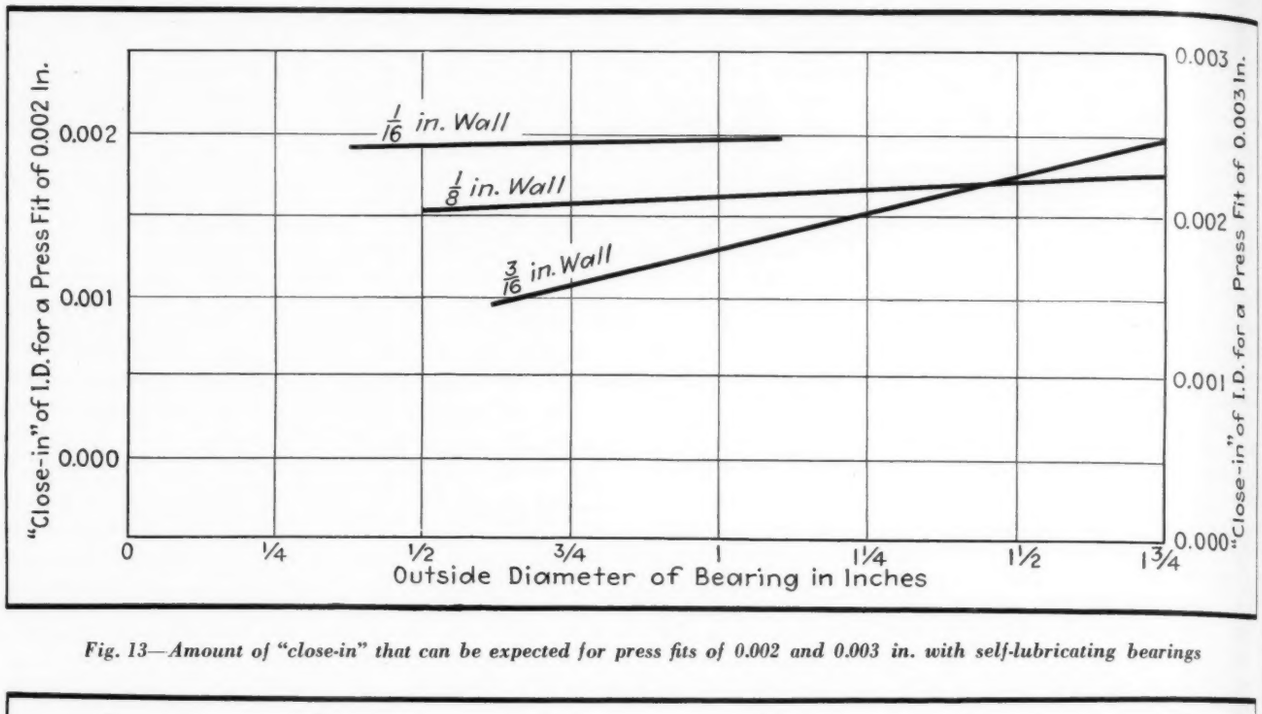

Fig. 13—Amount of "close-in" that can be expected for press fits of 0.002 and 0.003 in. with self-lubricating bearings

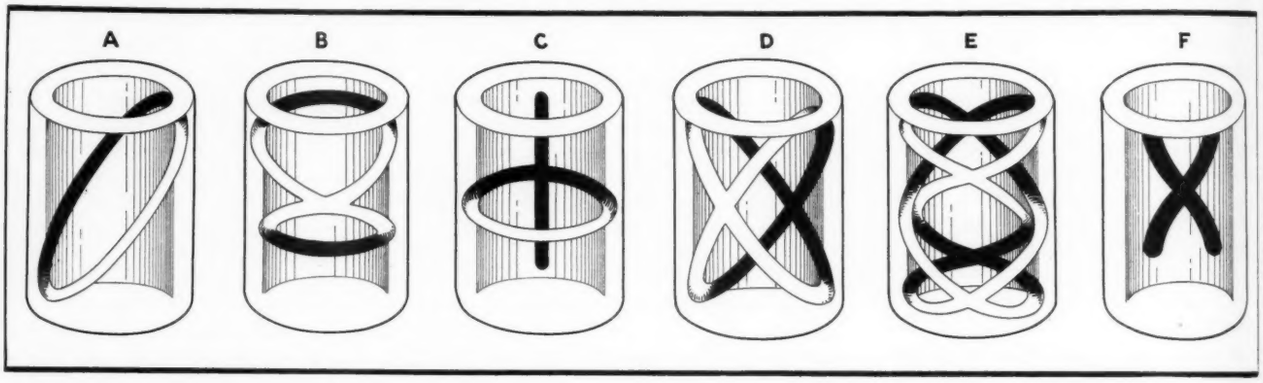

Fig. 14—Various types of oil grooves used to obtain uniform distribution of oil along the length of bearings

of the bore results which should be taken into consideration. Fig. 13 shows the results that can be expected.

These bearings can be made full and in split halves, with porosities ranging from 10 to 35 percent of the geometrical volume of the bearing. Standard manufacturing tolerances in inches are as follows:

	I.D. Up to 1½ in.	I.D. over 1½ in.
For I.D. and O.D.	+ 0.000 — 0.001	+ 0.000 — 0.0015
Eccentricity, max.	0.0015	0.002
Total indicator read.	0.003	0.004
Length	+ 0.005 — 0.005	+ 0.005 — 0.005

Closer tolerances are possible, however, the closer they are the higher will be the costs because of reduced die life and increased die costs, as well as more rigid manufacturing procedure.

From a manufacturing point of view bearings may be divided in two groups: (A) Precision insert interchangeable bearings which are manufactured to such close tolerances that no machining or finishing in assembly is necessary. (B) Bearings the bores of which are to be machined or finished at assembly. Both groups may be of the full round, full round split, or half type.

An important factor in connection with all types of bearings is that their backs must be in direct contact throughout their entire surface with and supported by the housing with no loose spots. This is necessary to secure maximum heat conduction and to prevent "breathing" under changing load. This condition can be checked by blueing the bearing backs in the housing or in inspection saddles having a hardened and ground bore corresponding to the upper limit of the housing bore.

The requirement of perfect backing leads to the importance of the height of precision insert half bearings and to the necessity of their having a certain amount of spread in the free state. The height of the bearing halves, after being snapped into the housing, must be slightly greater than half of the housing bore diameter in order to secure a pressure contact of the whole back with the housing when the pair is pressed together in assembly. The inside surface of precision half bearings should be slightly relieved towards the parting face in order to eliminate any distortion that may be caused by the crushing of the metal because of overheight.

To secure a desired clearance with precision insert bearings, the tolerances should be given with the wall thickness rather than with the bore of the bearing. A perfectly blued-in back and a closely controlled wall thickness over the whole bearing are the best guarantees for a controlled clearance. Modern bearing manufacturing is based on this principle. On the other hand, it is self-evident that this type of bearing

requires a closely aligned housing axis and closely controlled housing bore.

Designating the manufacturing tolerances for housing bore as t_1, wall thickness of bearing as t_2, and shaft diameter as t_3, the tolerance of the clearance will be t_1 plus $2t_2$ plus t_3. With t_2 equal to 0.00025 in., which is about the closest tolerance for the wall thickness of present day mass production of bearings, and both t_1 and t_3 equal to 0.001 in., the clearance tolerance becomes 0.0025 in. A closer tolerance for the clearance can be obtained by decreasing the tolerances t_1 and t_3 for the housing bore and the shaft, or by a design which provides finish machining of the bearing bore in assembly.

On the other hand, close wall thickness tolerances for bearings the bores of which are finish machined in assembly, increase costs unnecessarily.

The purpose of oil grooves is to assure proper distribution of the lubricant along the length of the bearing in the region just ahead of the loaded area (see Fig. 4, May *P.E.*). Complicated and elaborate grooves are in most bearings neither necessary nor useful; they render manufacturing more difficult, and, if not properly placed and executed, may do more harm than good because they may assist in interrupting the oil film.

Deep grooves should always be avoided and both edges of any oil groove should be rounded off to permit free entrance of the oil into the clearance.

Grooves should never be located in the high-pressure area of an oil lubricated sleeve bearing.

In order to obtain quick and uniform distribution of the oil along the length of the bearing, the oil groove should extend axially from the point of entrance and should stop short of the ends of the bearing to minimize oil leakage.

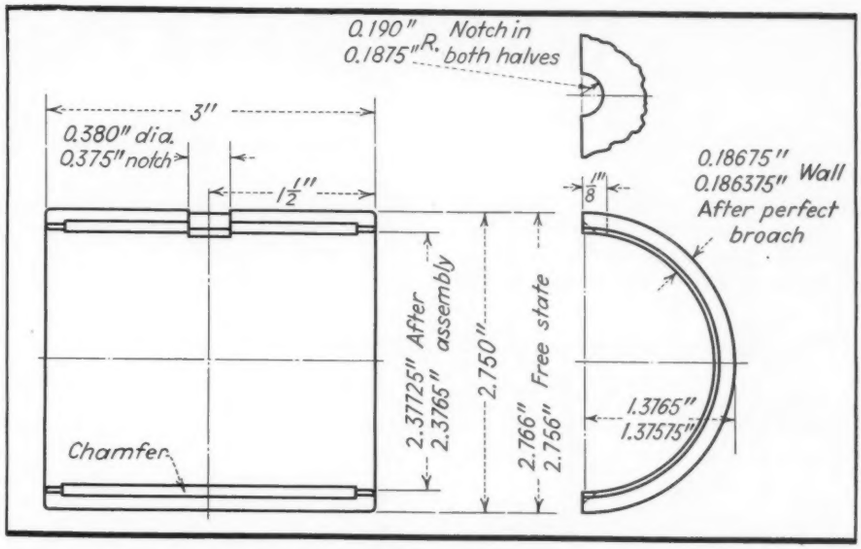

Fig. 15—Longitudinal chamfers at the mating surfaces of split-half bearings are sometimes sufficient to distribute oil along the length of the bearing

In applications where the direction of rotation changes, spiral oil grooves approaching the high-pressure area, like those shown in Figs. 14 (a) and (b), might be expedient.

In many types of split-half bearings, especially when pressure lubrication is used, longitudinal chamfers (relieves) on each side of the bearing halves, as shown in Fig. 15, are sufficient to secure distribution along the length of the bearing.

As to the points of the oil entry into the oil grooves, they should always be located ahead (relative to the direction of the shaft rotation) of the pressure area; that is, in the unloaded side in bearings with constant load direction.

In applications with changing load direction, the oil entry should be placed at points of minimum oil pressure (see Fig. 4, May *P.E.*). The angle α of shaft shifting, and with it the position of the high pressure area in the oil film, is determined by the constant C_1 and can be read directly from Fig. 5 (May, *P.E.*), the abcissa of which is C_1. The constant C_1 is also the abscissa of Fig. 7 (May *P.E.*) and its values for a given application c/d, h/d, f, and $\sqrt{Zn/p}$ can be taken from this figure.

For very long bearings, two oil entrances might be expedient or necessary, if so they should be connected by one axial distributing groove.

Table IV—Fundamental Types of Oil Grooving

Application	Type of Bearing	Bearing Support	Direction of		Method of Grooving
			Load	Rotation	
General purpose	Solid or two-part	Fixed in stationary housing	Unidirectional	Unidirectional	Straight groove, stopping short of each end
General purpose	Solid or two-part. Lubrication provided through shaft	Fixed in stationary housing	Unidirectional	Unidirectional or changing	Circular groove to coincide with oil exit in shaft and straight groove stopping short of each end. Fig. 14 (C)
General purpose	Solid	Fixed in moving housing (pulleys, gears, etc.)	Unidirectional or changing	Unidirectional or changing	Oval type groove. Fig. 14 (A)
General purpose	Solid or two-part	Fixed stationary housing	Unidirectional	Changing	Double spiral groove short of bearing ends, Fig. 14 (F)
General purpose	Solid	Fixed in stationary housing	Undirectional	Changing	Complete figure eight type of groove Fig. 14 (B)
General purpose	Two-part	Fixed in stationary or rotating housing	Undirectional or changing	Undirectional or changing	Longitudinal or circular grooves and/or chamfers on each side at parting line. Fig. 15
Slow speed, grease lubricated					Grooved as shown in Fig. 14 (D) and (E). Recommended only for grease or graphite lubrication

WELDED CONSTRUCTION

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The Lincoln Electric Company

AVAILABILITY OF MATERIALS, salvage of scrap, shop facilities, and speed in production, particularly during the war emergency, are major factors among the variables affecting selection of methods of fabrication of machine parts. While the practicability of any of these suggested designs may depend upon numerous variables, their chief value is in suggesting still other possible combinations of standard bars, shapes, plates, and tubing in common parts.

HAND LEVER OF CAST IRON REDESIGNED FOR WELDING

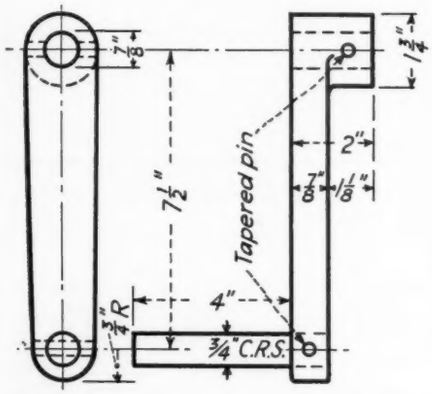


Fig. 1—Original cast hand lever weighs 4.1 lb.

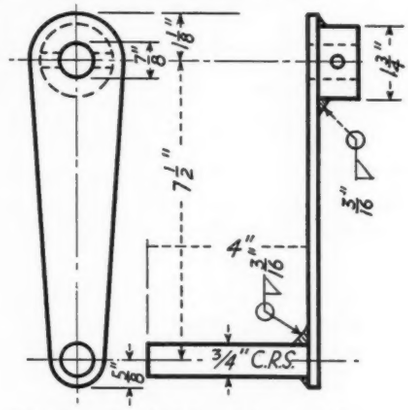


Fig. 2—Welded hand lever with arm of ¼-in. plate cut to shape

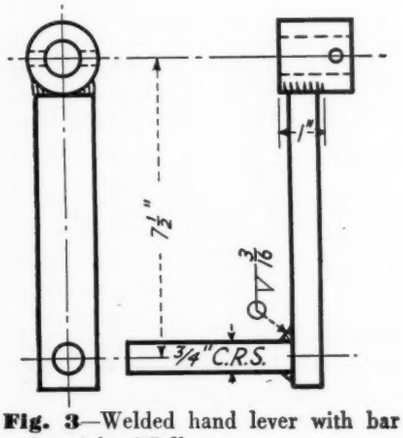


Fig. 3—Welded hand lever with bar arm weighs 3.7 lb.

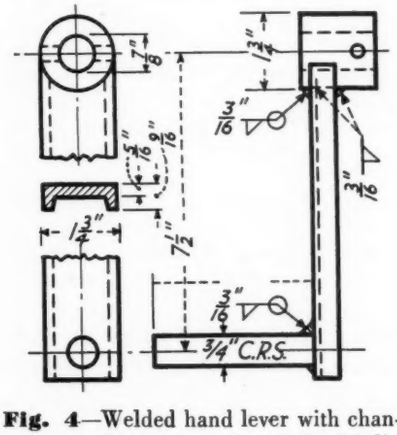


Fig. 4—Welded hand lever with channel arm shaped to hub weighs 2.7 lb.

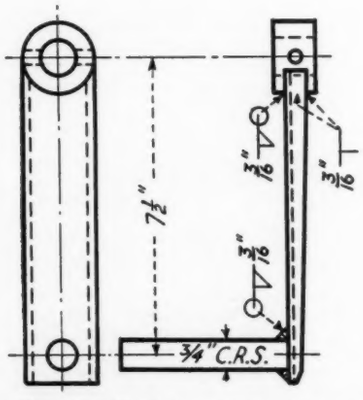


Fig. 5—Welded hand lever with formed channel arm weighs 2 lb.

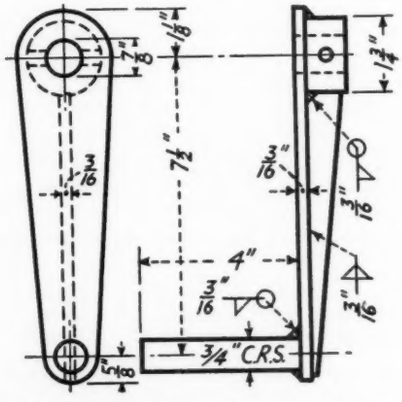


Fig. 6—Welded hand lever with formed tee section for arm weighs 1.8 lb.

CAST STEEL CLEVIS REDESIGNED FOR WELDING

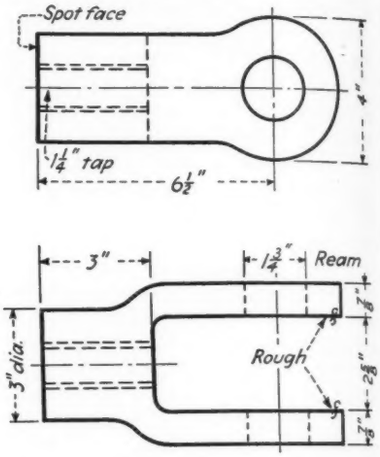


Fig. 7—Original cast clevis weighs 13.8 lb. after machining

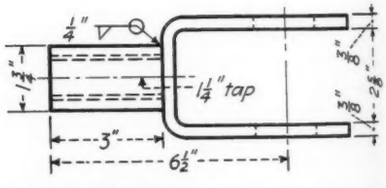


Fig. 8—Welded clevis made of tube and strap weighs 6 lb. Substitution of square for tube would increase weight to 7.6 lb. and add to the cost

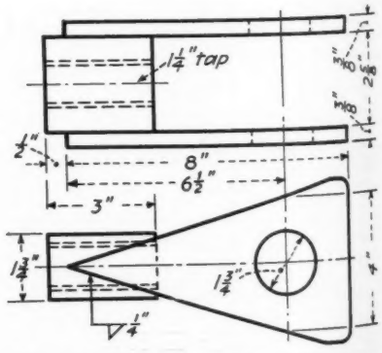


Fig. 9—Welded clevis with square and two straps avoids forming operation. It weighs 6.4 lb.

Suggestions for Typical Machine Parts

CAST STEEL EYE REDESIGNED FOR WELDING

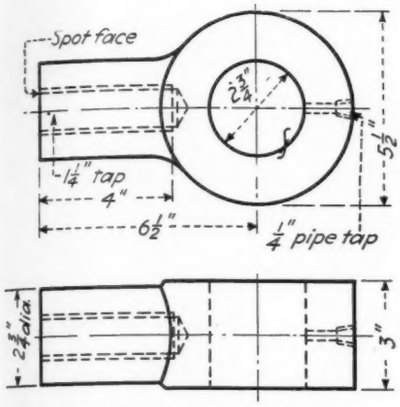


Fig. 10—Orig. cast eye weighs 23 lb. after machining

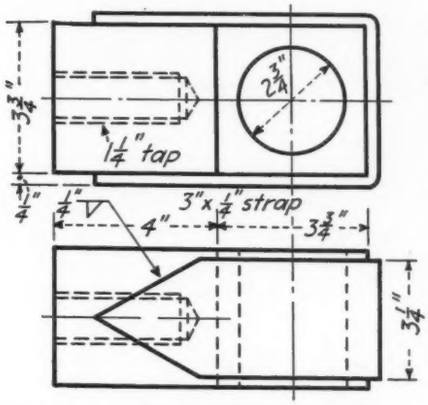


Fig. 11—Use of two square bars connected by strap saves scarfing the bar

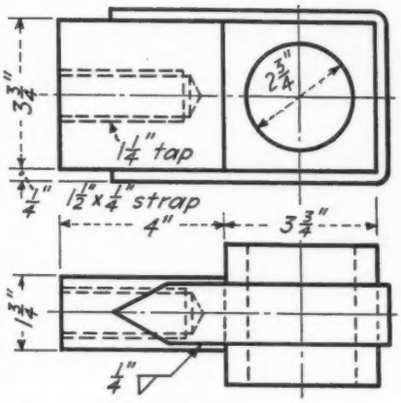


Fig. 12—Welded eye of two square bars improves the Fig. 11 design

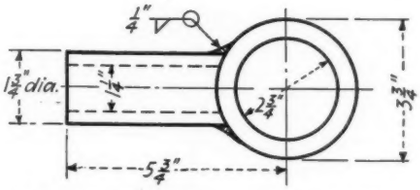


Fig. 13—Welded eye made with two tubes is an ideal design

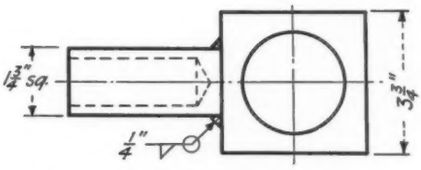


Fig. 14—Welded eye made of square and a flat bar section

CAST STEEL LEVER REDESIGNED FOR WELDING

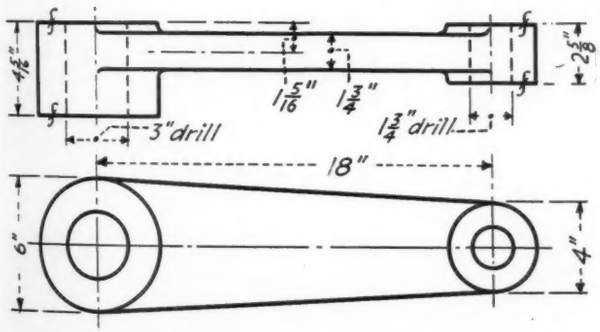


Fig. 15—Original cast lever weighs 62.5 lb.

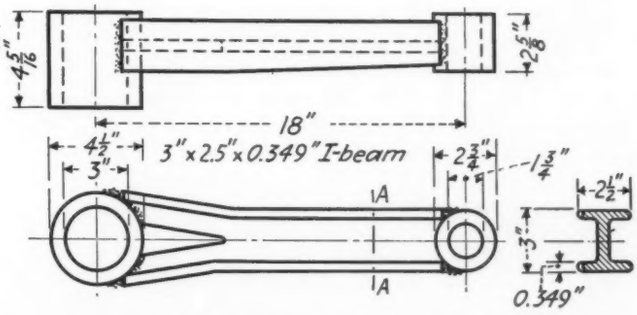


Fig. 16—Welded lever with T-section and plate

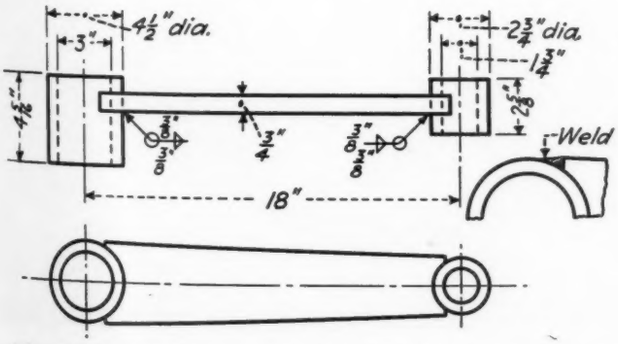


Fig. 17—Welded lever with hubs of tubing and web of bar weighs 34 lb. and is good enough for some uses

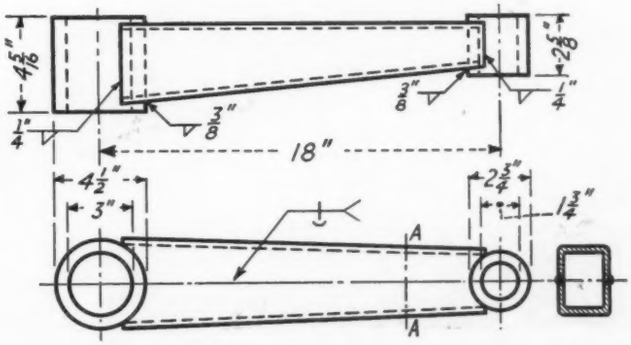


Fig. 18—Welded lever with formed U-sections is better, more economical and flexible design. It weighs 20.5 lb.

WELDED STRUCTURES

Causes of Deformation and Their Correction

GUSTAF JOHANSSON
Engineer, Link-Belt Speeder Corporation

It is the author's intention to point out some of the unfavorable conditions caused by the lack of a fixed yardstick or rule governing the welding of structures. Unexpected misfits and defects which develop during welding can largely be eliminated by proper foresight in the engineering department. A number of specifications to be noted on the design drawings are suggested.

WELDED PARTS which are made in quantities for mass production seldom allow exact fits at assembly, thus making it necessary to perform extra machine operations to obtain clearances and alignment. This is particularly true of large frames. Hubs are often too short or too long, or off to one side or the other. Pads that are to be planed may not be correctly placed for machining. Ribs may be out of line; warping and shrinkage during welding may have twisted parts out of place. Other defects may also necessitate extra machine work, additional welding and set-up work. Furthermore, machining extensive surfaces of large parts which cannot be annealed becomes a problem because the strains introduced in the unit during the welding and cooling processes become active again when material is removed. Lesser troubles not quite as serious but sometimes as costly occur when ribs, webs and flanges are displaced enough to cause interferences with proper placement of bolts, pins, shafts or other parts.

Structure shown in Fig. 1 provides an example of a typical problem. Two outer longitudinal members of the fabricated frame are 16 in. deep beams about 12½ ft. long The inside of the unit, not visible in the illustration, consists of a number of cross beams, webs and hubs. The whole is covered with heavy plate, top and bottom. The width of the plate is about 5 ft. 2 in. A number of other brackets and pieces of machinery are later added to the frame as shown in the views in Fig. 2. It thus becomes obvious that the welded frame must be accurate.

Causes of Deformation

ORDER OF WELDING. When the cut material is gathered together for the welder, the usual procedure is to clamp and tack-weld certain logical small sub units, or even finish welding them. Then follows the assembling of larger parts into the main unit. Finally coverplates are attached and welded. Welders of experience and skill will do all this with a minimum of distortion, but no two men will end up with the same results. The order and technique are two variables which differ even with the most experienced operators. Such a thing as one left-handed and one right-handed welder will alone make differences. Thus, there are any number of ways to weld together any structure, depending upon the production layout, supervision, type of welder, and, often, personal opinion. A variation in any of these factors will cause the welded structure to expand and contract differently to such a degree that it will be beyond a man's capability to foresee how closely final dimensions will check with those specified on the engineer's drawings.

BEAD, TIME AND HEAT FACTORS. Variations occur in the size of the bead laid down, the degree of heat used, and the length of time spent on the welding operation. One welder may have a relatively cool part after the operation, another may end up with the same part overheated. If these parts are fitted to others for welding, the two indepen-

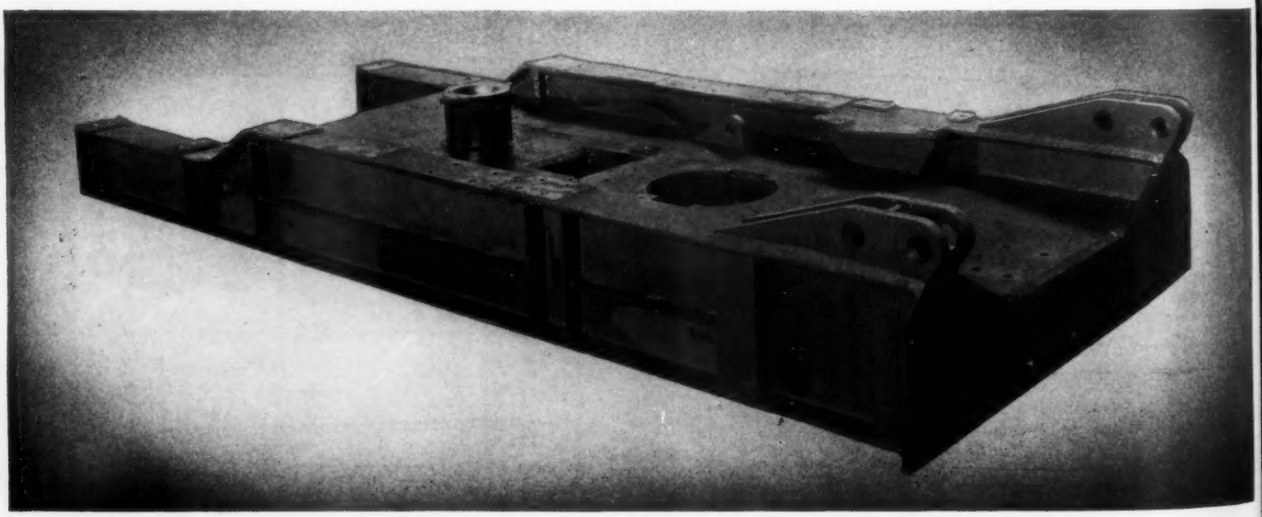


Fig. 1—Produced in large quantities, this base of a heavy welded structure, with large side beams and transverse internal members, cannot be fabricated to specified dimensions unless conditions and procedure for welding are set up by the engineering department

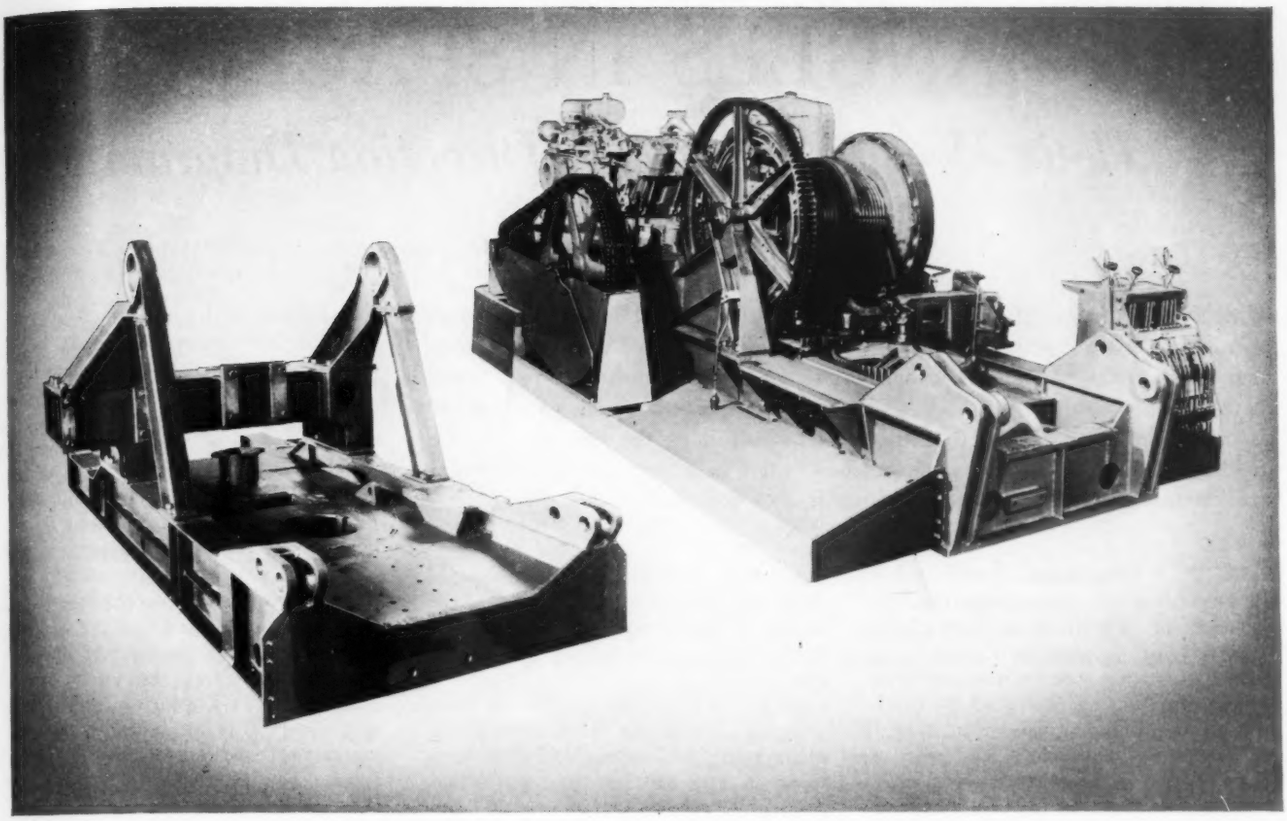


Fig. 2—There are more chances for errors in the assembly of the welded frame and machinery added to the base shown in Fig. 1 if welders, working on identical parts, do not follow the same welding routine and work in shops of regulated temperature

ently worked parts will have different final dimensions. Welders making parts large enough to require days of work will have different results on duplicate parts if long stops occur between working periods. When leaving for dinner, or at night, cooling off periods take place in welds at widely different places in the progress of the operation. The result is a change in shrinkage for similar parts.

WORK-ROOM CONDITIONS. Heating conditions in the welding shop are also of great importance to uniformity of welding. If all parts to be welded are cut from the same pattern but brought in to be assembled and welded in rooms of different temperatures, results cannot be identical.

WELDER'S SKILL. Another factor to consider as a cause of disturbance is the skill of the welding supervisor and the welder. In spite of all precautions that are taken to obtain uniformity, the experienced welder's work will differ from that of the less skillful welder.

Minimizing Welding Defects

A solution to most of these troubles is the evaluation of a rule of guidance whereby identical unavoidable errors are committed on all parts. Each shop may have a different procedure, but with a universally accepted procedure, similar parts from different locations will have a much better chance of coming out alike.

ORDER OF WELDING. To prevent errors caused by welding different parts together in different orders, the designer and production engineer must make a study of the part to be welded and consider the most logical point from which to start the work, in what order each part is to be welded, and how parts are to be assembled into a unit by welding. After a few units have been worked up along this plan and a satisfactory order found, each piece should be marked with a number in the order in which it is to be welded and, if important enough, also marked where the welder starts and finishes the weld. Extra supervision is necessary and perhaps a time study should be made on a few units to establish the best obtainable order of welding.

BEAD, TIME AND HEAT FACTORS. Size of bead for each operation should be standardized and specified on drawings. After a speed of operation is made standard it may be scheduled so that quitting time happens at the same stages of the work for similar units. A uniform rule is needed for heat control. For example, a rule might state that if the welder cannot lay his bare hands within ten or twelve inches from where he is welding, he should stop long enough for the part to cool off. Preheating or a means of cooling off the part may be solutions.

WORK-ROOM CONDITIONS. With the temperature of the work-room held at a given level, say never below 65 deg. F., and cool drafty places eliminated, the workroom problem is solved. Summer heat causes little disturbance whereas the cold, particularly when below freezing, is objectionable. Outdoor work in winter should be done under cover of a tent; often this must be heated.

WELDER'S SKILL. Regularly, say every month or every other month, it is suggested that welders produce test pieces for checking for workmanship and strength by the engineering department. It is well also to make a periodic check of engineering specifications to ascertain whether the best fabrication method is employed. For example, it may happen that a part which is being welded might be cast with better results, and vice versa. Thus, the welder or the foundryman may not have to overcome difficulties which, with proper engineering planning, might be avoided before they become serious.

ANGLES IN SPACE

Their Measurement on a Direction Diagram

HERBERT H. STEVENS, JR.

Graphical measurement of space angles whose sides are oblique to the planes of all conventional orthographic views can be accomplished simply with only one auxiliary construction. A straight-forward procedure in three steps is given here. This is followed by a discussion of the principles upon which the method is based and accompanied by illustrations which show the flexibility of the method. More than one angle can be constructed on a single diagram. Graphical measurement of the lengths of lines is also described in the article.

IN THE conventional orthographic projection drawings of constructions such as aircraft motor mountings, piping layouts, hoppers and many sheet metal structures, some of the intersecting lines do not lie in any of the three planes of projection. Under such conditions it is impossible to measure directly the angle between two such members or lines. It can be done only by constructing one or more auxiliary views. In the conventional method this is cumbersome because usually several views are necessary and errors are likely to occur in constructing them. Also, the process is tedious, time-consuming and takes up considerable space on the drawing paper.

By the use of the method shown here, it is possible to determine the angle between any two intersecting lines that do not lie in any of the three planes of projection in the orthographic system. The method requires only one auxiliary construction. This method can also be applied for determining the lengths of lines that do not lie in any of the planes of projection. The isometric views presented here are shown only to clarify the proof of the procedure and are not required for measurement of the angles or lines.

In Fig. 1 is an example of the most general case of two lines intersecting at a point, but neither of the lines lying in any of the three projection planes. The angle of intersection between the lines is the angle made by the lines *AB* and *BC*. In Fig. 2 the lines *AB* and *BC* are shown in plan, elevation and side views. Fig. 3 shows three steps in the auxiliary construction by which the angle is determined. A brief summarization of the procedure follows.

Summarized Procedure

Draw a circle of any convenient radius with *X* and *Y* axes through its center point *O*. Through the point *O* draw lines parallel to the lines *AB* and *BC* in the elevation view of Fig. 2. Fig. 3(*A*) shows these lines.

From the point *S'* at the intersection of the *X*-axis with the circle, draw lines parallel to the lines *AB* and *BC* in the side view of Fig. 2. Where these lines intersect the *Y*-axis at A_1 and C_1 in Fig. 3(*B*), project horizontal lines to intersect with the lines that were drawn parallel to the projected sides of the angle in the elevation view. Join these points of intersection, D_{AB} and D_{BC}.

Referring to Fig 3(*C*), the next step is to erect a perpendicular to D_{AB} D_{BC} passing through the center of the circle. Draw from the center of the circle a line perpendicular to *OT*, the line just drawn, intersecting the circle at the point *S"*. With *T* as a center and *TS"* as the radius, swing an arc intersecting the line *OT* at the point S_B. The angle formed by joining S_B with the points D_{AB} and D_{BC} is the true angle between *AB* and *BC*, the legs of the angle.

Direction Diagram

The proof of the above construction is based upon simple geometric relationships. For convenience the auxiliary construction is called a "direction diagram" because the principal lines in the construction are drawn parallel to corresponding lines in two of the planes of the projection. It should be noted that any two planes of the orthographic projection can be used. The elevation and side view were selected arbitrarily in the example outlined above.

The construction procedure is based upon the assumption of a point *S* perpendicularly above the center *O* of the circle at a height equal to the radius of the circle of the direction diagram, as shown in Fig. 4. This point *S* is imagined to coincide with the apex of the angle to be measured, *ABC* or α. The plane of the circle may be assumed parallel with any of the three views of the orthographic projection. Thus in Fig. 3 the plane of the circle is assumed parallel with the elevation view in Fig. 2 and the lines *A'B'* and *B"C'* are drawn parallel with *AB* and *BC* in this view. (In Figs. 5 and 6 the plane of the circle is assumed parallel to the side and plan views respectively.)

If two points are determined at which each of the two sides of the angle drawn from the point *S* in space intersect the plane of the paper, a line joining those

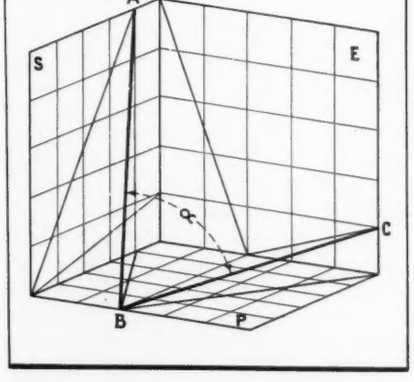


Fig. 1—Typical example of a problem in measuring an angle in space

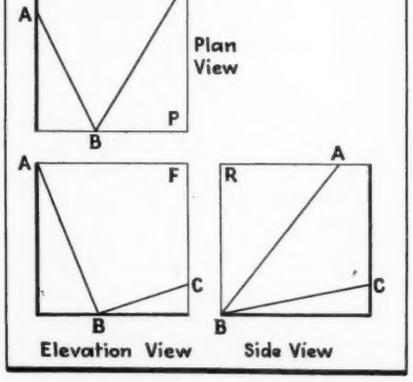


Fig. 2—Conventional orthographic projections of angle to be measured

points would locate the intersection of the plane of the angle ABC with the plane of the paper, or of the circle. With this intersection determined, it is a simple matter to rotate the plane of the angle about the line of intersection until the angle lies wholly in the plane of the paper where it can be measured.

These two points will lie on the lines $A'B'$ and $B''C'$. The geometric relations involved in locating the points will be evident from the fact that if the plane of the paper is parallel to the front view, a plane through the point S and the Y-axis will be parallel to the side view. Lines parallel to the side view projections may be assumed to be in this plane. If this plane is rotated about the Y-axis the point S may be made to fall on S', because the distance OS perpendicular to the plane of the paper was defined as equal to the radius R of the construction circle. The directions of the projected sides of the angle in this plane now become parallel to projections in the side view of Fig. 2. These lines are shown in Fig. 3(B) as $S'A_s$ and $S'C_s$.

These lines intersect the Y-axis and locate the distance from the X-axis at which the legs of the angles intersect the plane of the circle. This is evident from the isometric view in Fig. 4. By drawing lines from these intersections parallel to the X-axis, the points D_{AB} and D_{BC} are located. These are the points at which the legs of the angle pierce the plane of the paper when the apex of the angle is at the point S above the plane of the paper. The line D_{AB} D_{BC} is the intersection of the plane of the angle with the plane of the paper.

It is now necessary to rotate the plane $SD_{AB}D_{BC}$ in Fig. 4 about the axis $D_{AB}D_{BC}$ until the point S falls in the plane of the paper. From the geometry of the construction, the point S will rotate in a plane perpendicular to the paper and intersect the plane of the paper along the line OT in Fig. 3(C).

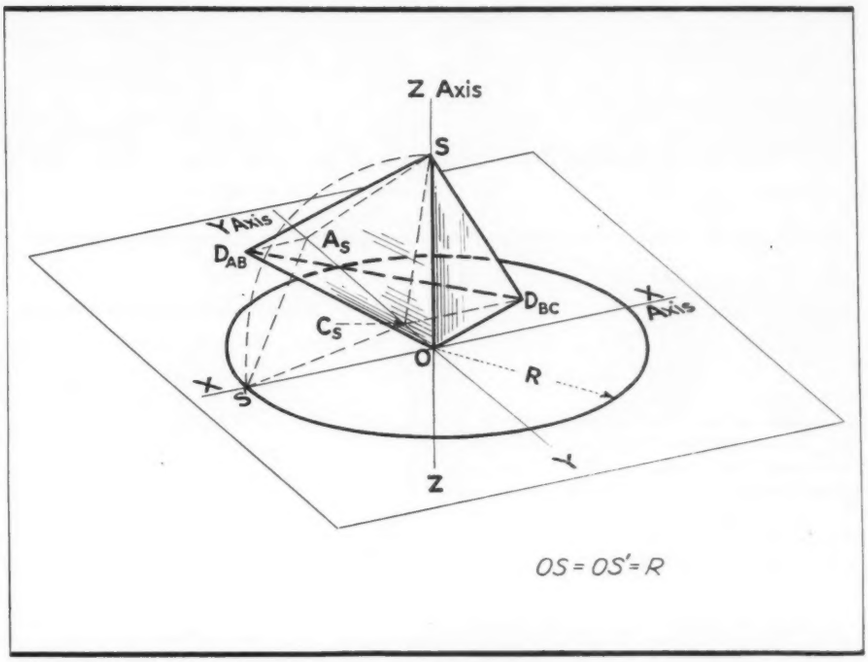


Fig. 4—Perspective view of "direction diagram" showing point S above the plane of the diagram and position of the plane of the angle to be measured

The radius of rotation of point S will be the true length of the line ST, and also the hypotenuse of a right triangle whose other two sides are the distance between the center of the circle and the point S, and the distance between the center of the circle and the axis $D_{AB}D_{BC}$. This radius can be determined directly on the direction diagram by swinging this triangle into the plane of the diagram, that is, by drawing a line perpendicular to the base OT of the triangle intersecting the construction circle at S''. A line TS'' completing the triangle will be the true length of the line ST.

With T as the center and TS'' as the radius, an arc swung from S'' and intersecting the line OT at S_B will measure the true length of ST on the line OT. The point S_B will be the location of the apex of the angle ABC when that angle lies wholly in the plane of the paper. Thus, the angle $D_{AB}S_BD_{BC}$ is the true angle formed by the intersection of lines AB and BC.

The determination of the angle is not limited to the elevation and plan views. The outlined procedure may be applied to other views equally well, as in Figs. 5 and 6. In Figs. 5, in addition to making the plane of the circle parallel to the side view, an alternate construction for locating the points D_{AB} and D_{BC} is shown. The plane through S and the X-axis, which is parallel to the plan view, is rotated so that S falls at S' at

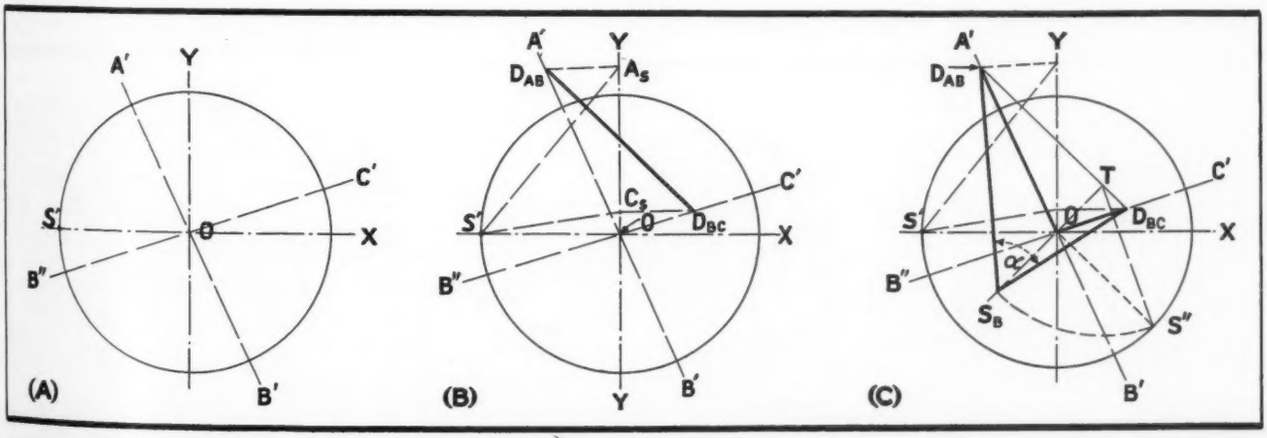


Fig. 3—Three steps in the graphical measurement of the angle are: (A) selection of the view to which the diagram is parallel, (B) finding the intersection of the planes of the angle and of the diagram, and (C) laying out the true angle

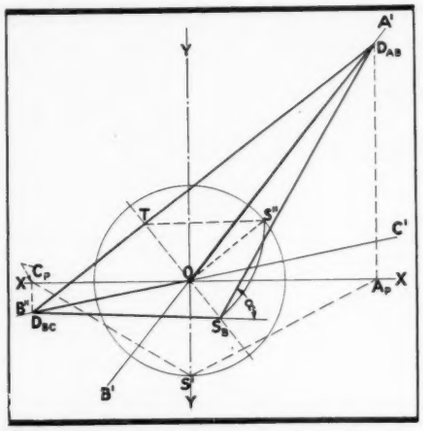


Fig. 5—An alternate construction for determining the angle α, starting with a plane parallel to the side view and using the plan view projections to locate the line of intersection of the planes of the angle and of the diagram

the intersection of the *Y*-axis and the circle. The lines C_pS' and A_pS' are parallel to *AB* and *BC* in Fig. 2, plan view.

Three Angles on One Diagram

When two more lines, such as *AZ* and *CW* in Fig. 7 makes angles with *AB* and *BC*, their angles may be determined on the same auxiliary diagram. These lines illustrate special cases since *AZ* is perpendicular to the plane of the diagram as drawn in Fig. 3, and *CW* is parallel to it.

The angle *ZAB* in Fig. 7 is determined almost the same as before, assuming the apex of the angle is at the point *S* and the plane of the diagram is parallel to the plane of the elevation view as before. The line *ZA* must intersect the plane of the paper at *O*, that is, D_{ZA} is at the point *O*. D_{AB} is already located. To get the mental picture it may be assumed that the sides of the angle are extended through *A* in Fig. 7, as indicated by the dotted lines.

In following the summarized outline of procedure it will be noted that the point *T*, referred to in connection with Fig. 3, is now at the point *O* and that the line parallel with $D_{AB}D_{ZA}$ coincides with the line. The desired angle β in Fig. 7 is taken from a plane swung down from the space point *S*, as before.

Similarly, the angle *BCW* may be assumed to have its apex at the space

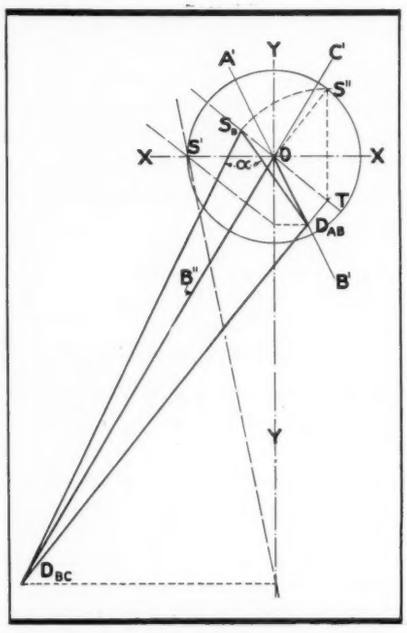


Fig. 6—An alternate construction for determining the angle α, starting with the plane of the diagram parallel to the plan view and using the side view

point *S*. The line *BC*, prolonged through *C*, will intersect the plane of the diagram at the same point as in Fig. 3. The line *CW* does not intersect the plane of the diagram because it is parallel to the plane. However, the direction to the theoretical point at infinity is indicated as the dashed line through *O* parallel to the actual line *CW*, or its true projection in the elevation view.

In following the summarized outline of procedure for determining the angle, the points of intersection of the sides of the angle with the plane of the paper are assumed joined when a line is drawn through D_{BC} parallel to *CW*. The other steps are the same as outlined except that the angle is formed by joining *S*, (corresponds to S_c in Fig. 3) with D_{BC} and the imaginary point, *DCW*, the latter line being parallel to *CW* in Fig. 7. This step may be omitted, however, because the desired angle may be formed also by lines shown radiating from the point D_{BC}, as shown.

Length of Lines

Since the lengths of lines such as those in the above example are usually required in addition to the angle between them, it is of further interest to show how they also may be determined on the direction diagram. This is illustrated in Fig. 8 which starts with the points of intersection of the lines with the plane of the diagram.

The construction is shown for both lines *AB* and *BC*, but the following procedure describes only the determination of the length of *AB*.

1. Draw *OA* through D_{AB}, its length being equal to the projected length of *AB* in the view to which the plane of the diagram is parallel (in this instance the elevation view).
2. Draw OS_1 perpendicular to *OA*.
3. Draw S_1D_{AB}.

This is the true length of that portion of *AB* between the apex of the angle and the plane of the diagram.

4. Draw *AB'*, the true length of *AB*, parallel to S_1D_{AB}.

The line S_1A' shows the position of the line *AB* after it is swung down into the plane of the diagram, assuming the apex *B* of the angle was at *S*, the point in space above the diagram.

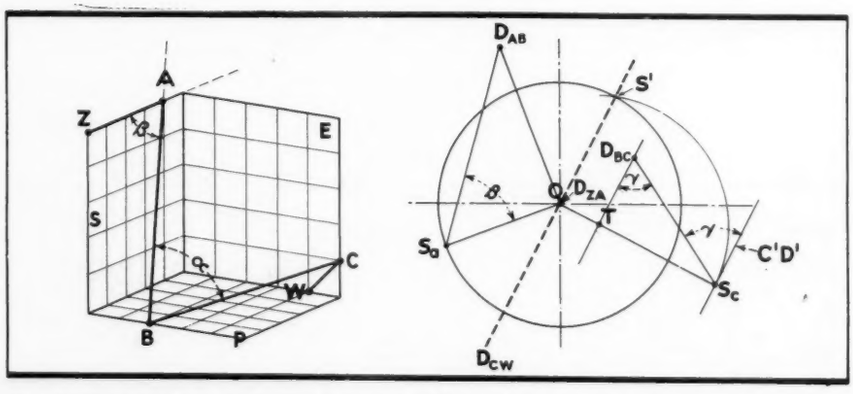


Fig. 7—Construction for determining two additional angles on the same diagram using points previously located

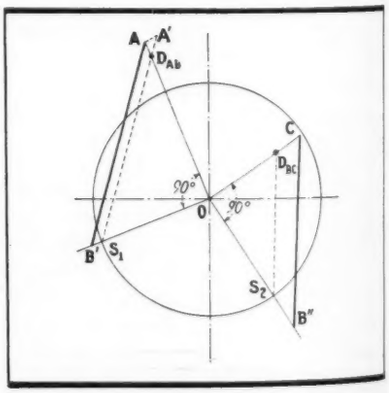
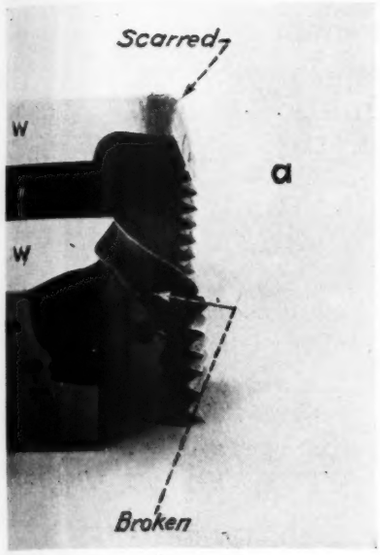
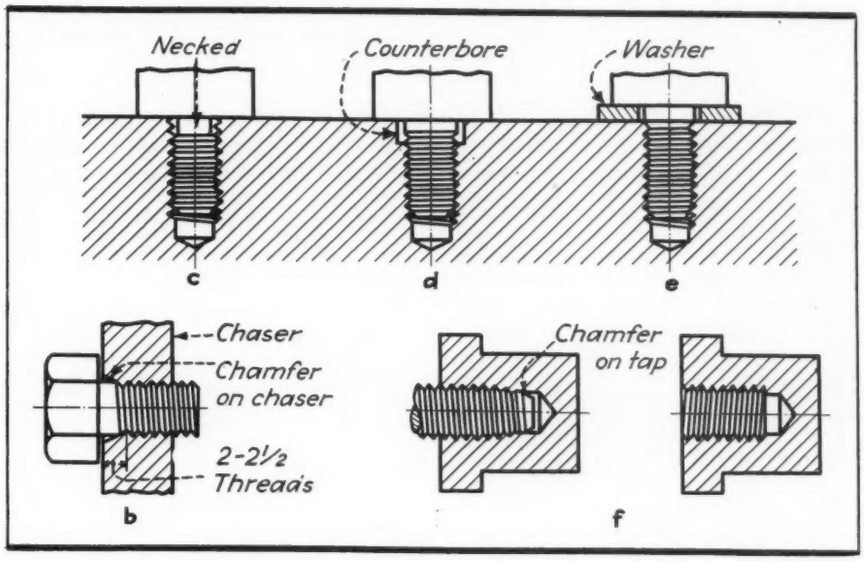


Fig. 8—Construction for determining true lengths of lines AB and BC

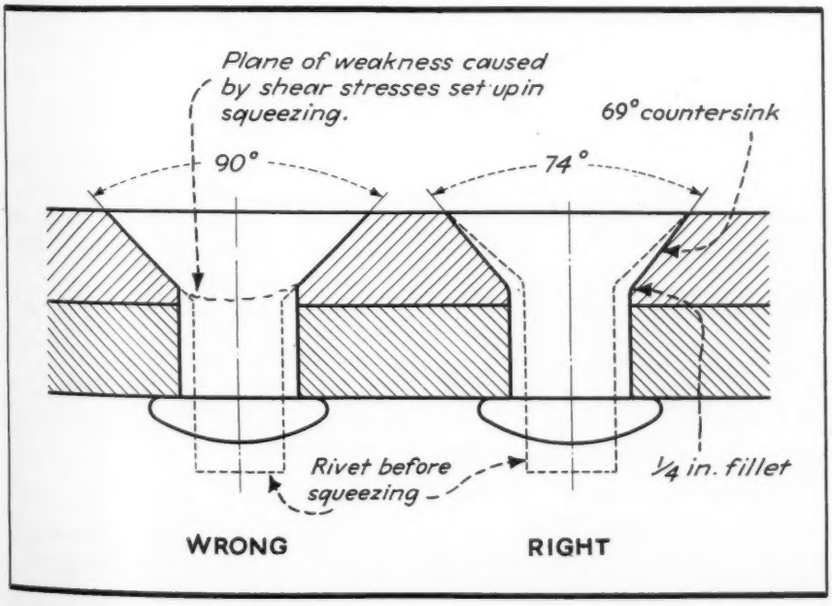
Causes and Cures





Seriously hampering war production, an increasingly large proportion of screw and threaded parts specify a full thread close to the shoulder—in many cases without consideration of serious production difficulties in threading close to shoulder, die head manufacturers report. As shown in (b), a chamfer 2 to 2½ threads long on the chaser is needed for good thread cutting. Die chasers with shorter chamfers can be made, but they are special, cost more, and do not give as good a finish, particularly on stainless steel, chromium-nickel steels, and other alloy steels. Short chamfer chasers also chip or break more easily, have shorter life per grind, and require slower cutting speeds. Hitting the shoulder of the threaded part when trying to cut threads close to the shoulder is chief cause of chaser scarring and breakage illustrated in (a).

Wherever possible, do not specify full threads closer to the shoulder than 2½ to 3 threads. Where screw parts must be screwed down to the head into tapped holes, avoid threading close to shoulder by necking or recessing the screw as shown in (c) by counterboring or countersinking the tapped holes as shown in (d), or by using washers as shown in (e). Similar considerations (f) should apply in specifying depth of tapped hole; drilled hole should be several threads deeper than required depth of tapped hole to allow clearance.



Cold squeezed rivets with countersunk heads were found to be failing at relatively low loads in one application; the heads popped off. They were of the 90 deg. type, set in 90 deg. countersunk holes as shown at left. Investigation showed that flow of metal in the shank and lower part of the head was setting up severe shear stresses at the neck, above which flow of metal was slight. This caused partial shear fracture at the neck, with subsequent weakening of the rivet. Cure: switch to 74-deg. countersunk rivets with generous fillet at junction of head and shank, set in 69 deg. countersunk holes. As can be seen in the view at right, flow of metal now is uniform.

PRODUCT ENGINEERING will pay a minimum of $3 for each example published in Causes and Cures. Where illustrations are necessary, include drawings, rough sketches or photographs.

DEFLECTION OF BEAMS

Under Simultaneous Axial and Transverse Loads

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Carnegie Institute of Technology

A method for quickly obtaining solutions of differential equations involved in determining the flexure of beams subjected to axial loading as well as transverse loading. The method is based on the use of the Laplace transformation.

In problems relating to the bending of beams or columns under simultaneous transverse and axial loads, where x and y are the coordinate axes of the elastic curve with y taken positive downwards,

M = bending moment at the cross-section through the point in question.
I = moment of inertia of the cross-section with respect to the neutral axis, and
E = modulus of elasticity

and with the usual assumptions of small deflections, plane of cross-section before bending remains plane after bending and homogeneity implied, the relationship between curvature and moment is

$$\frac{d^2y}{dx^2} = -\frac{M}{EI} \qquad (1)$$

If E and I are constants, and M varies as some function of x and y, then Equation (1) can be expressed for columns as

$$\frac{d^2y}{dx^2} + k^2y = f(x) \qquad (2)$$

where k^2 is a constant.

Instead of solving Equation (2) by the standard procedures outlined in texts on differential equations for each case when $f(x)$ changes under the conditions imposed by the loading, another solution can be obtained by the Laplace transformation (Doetsch, Theorie und Anwendung der Laplace—Transformation, 1937.) which leads to an integral equation solution which can further be simplified to simple differentiation. By use of the Laplace transformation the solution of Equation (2) is

$$y(x) = C_1 \cos kx + C_2 \sin kx + \frac{1}{k}\int_0^x f(x') \sin k(x-x')\,dx' \qquad (3)$$

where C_1 and C_2 are arbitrary constants, and x' the variable of integration. It is evident that in Equation (3) the first two terms are the complementary solution and the last term the particular integral. Integration by parts of the particular integral gives

$$\frac{1}{k}\int_0^x f(x') \sin k(x-x')\,dx' = \frac{f(x)}{k^2} - \frac{f^{ii}(x)}{k^4} + \frac{f^{iv}(x)}{k^6} - \ldots \frac{(-1)^n f^{2n}(x)}{k^{2n+2}} \qquad (4)$$
$$(n = 0, 1, 2, \ldots)$$

where $f^{ii}(x)$, $f^{iv}(x)$, . . . $f^{2n}(x)$ are respectively the second, fourth . . . $2n$th derivatives of $f(x)$. The successive $2n$th derivatives are computed until $f(x)$ vanishes.

Thus the general solution of Equation (2) becomes

$$y(x) = C_1 \cos kx + C_2 \sin kx + \sum_{n=0}^{n'} \frac{(-1)^n f^{2n}(x)}{k^{2n+2}} \qquad (n = 0, 1, 2 \ldots) \qquad (5)$$

The solution in this form represents a short and convenient method for obtaining the equation of the elastic line. Obtaining the solution of Equation (2) now becomes one of simple differentiation.

Applications

GENERAL CASE. A homogeneous column as shown in Fig. 1, of length l and of uniform cross-section is subjected to axial load P applied at the center of the cross section, moments M_1 and M_2 applied at the ends of the column and a continuously distributed transverse load of the form

$$q = \frac{w\,x^n}{l^n}$$

where

$q = 0$ when $x = 0$ and
$q = w$ when $x = l$

Thus when

$n = 0$, $q = w$, a uniformly distributed load
$n = 1$, $q = \frac{w}{l}x$, triangularly distributed load
$n = 2$, $q = \frac{w}{l^2}x^2$, parabolically distributed load

Then the curvature equation becomes:

$$\frac{d^2y}{dx^2} = \frac{1}{EI}\left\{-Py + \frac{(M_1 - M_2)}{l}x - M_1 - \frac{w\,l}{(n+1)(n+2)}x + \frac{w}{(n+1)(n+2)} \times \frac{x^{n+2}}{l^n}\right\}$$

or writing this in the standard form let

$$k^2 = P/EI,$$

then

$$\frac{d^2y}{dx^2} + k^2y = \frac{1}{EI}\left\{\frac{(M_1 - M_2)}{l}x - M_1 + \frac{w}{(n+1)(n+2)}\left(\frac{x^{n+2}}{l^n} - l\,x\right)\right\} \qquad (6)$$

Solution to Equation (6) from Equation (5) is

$$y(x) = C_1 \cos kx + C_2 \sin kx + \frac{1}{P}\left[\frac{(M_1 - M_2)}{l}x - M_1\right] + \frac{w}{P(n+1)(n+2)\,l^n} \times (x^{n+2} - l^{n+1}x) - \frac{(n+2)(n+1)x^n}{k^2} + \frac{(n+2)(n+1)n(n-1)x^{n-2}}{k^4} \qquad (7)$$

The Equation (7) can be written in a compact form as

$$y(x) = C_1 \cos kx + C_2 \sin kx + \frac{1}{P}\left[\left(\frac{M_1 - M_2}{l}\right)x - M_1\right] + \frac{w}{P(n+1)(n+2)\,l^n} \times (x^{n+2} - l^{n+1}x) + \frac{w}{Pl^n} \times \sum_{m=1}^{1+\frac{n}{2}} (-1)^m \frac{n!}{[n-2(m-1)]!} \frac{x^{n-2(m-1)}}{k^{2m}} \qquad (8)$$

where the summation implies a finite sum over the range from

$m = 1, 2, 3 \ldots$ to the highest integer contained in the quantity $1 + \frac{n}{2}$

For example, when n equals 3, case of distributed load varying as a cubical parabola

the quantity $1 + \frac{n}{2} = 1 + \frac{3}{2} = 2\frac{1}{2}$

thus the highest integer contained is 2, therefore m takes on values 1 and 2 when n equals 3.

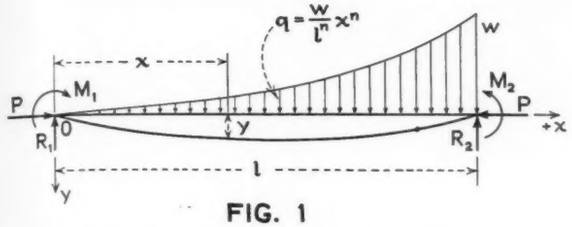


FIG. 1

General Case of Axial Compression and Continuously Distributed Transverse Load

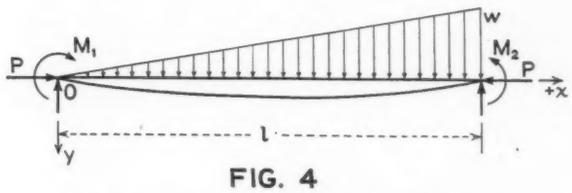


FIG. 4

CASE III. Triangularly Distributed Load, both ends supported

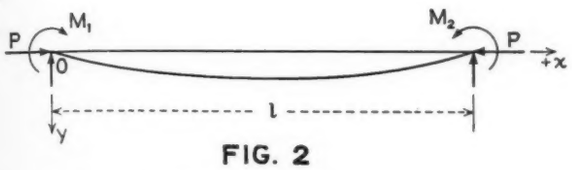


FIG. 2

CASE I. No Transverse Load, unequal end moments

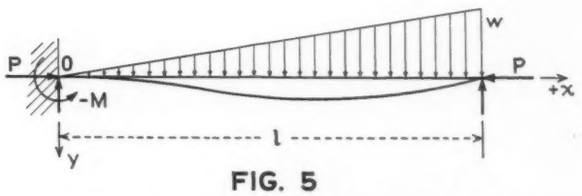


FIG. 5

CASE III (A). Triangularly Distributed Load, one end fixed, other end supported

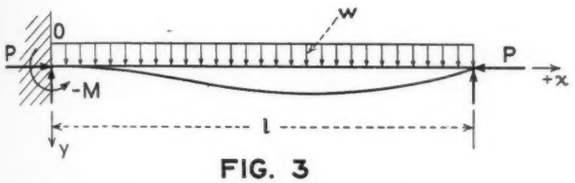


FIG. 3

CASE II. Uniform Transverse Load, one end fixed, other end supported

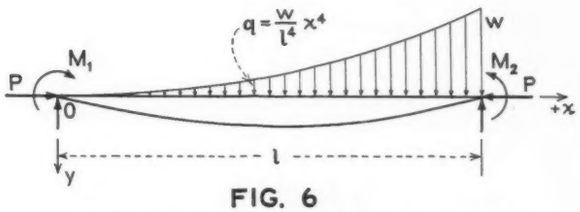


FIG. 6

CASE IV. Parabolically Distributed Load, both ends supported

Figs. 1 to 6—Beams under axial compression and transverse loading, some with both ends supported and some with one end fixed

Then Equation (8) expanded for n equals 3 is

$$y(x) = C_1 \cos kx + C_2 \sin kx + \frac{1}{P}\left(\frac{M_1 - M_2}{l}x - M_1\right) + \frac{w}{P(4)(5)l^3} \times (x^5 - l^4 x) + \frac{w}{Pl^2}\left[(-1)\frac{3!}{3!}\frac{x^3}{k^2} + (-1)^2\frac{3!}{1}\frac{x}{k^4}\right]$$

Further simplification of Equation (8) can be made by letting

$$Q_n(x) = \frac{w}{Pl^n}\left[\frac{x^{n+2} - l^{n+2}x}{(n+1)(n+2)} + \sum_{m=1}^{1+\frac{n}{2}} \frac{(-1)^m}{[n-2(m-1)]!}\frac{n!}{}\frac{x^{n-2(m-1)}}{k^{2m}}\right]$$

and evaluating the polynominals $Q_n(x)$ for n equal to 0, 1, 2. . . . This is done only as a matter of convenience; thus

$$Q_0(x) = \frac{w}{P}\left(\frac{x^2 - lx}{2} - \frac{1}{k^2}\right)$$

$$Q_1(x) = \frac{w}{P}\left(\frac{x^2 - lx}{6} - \frac{x}{k^2}\right)$$

$$Q_2(x) = \frac{w}{Pl^2}\left(\frac{x^4 - l^3 x}{12} - \frac{x^2}{k^2} + \frac{2}{k^4}\right)$$

$$Q_3(x) = \frac{w}{Pl^3}\left(\frac{x^5 - l^4 x}{20} - \frac{x^3}{k^2} + \frac{6x}{k^4}\right)$$

$$Q_4(x) = \frac{w}{Pl^4}\left(\frac{x^6 - l^5 x}{30} - \frac{x^4}{k^2} + \frac{12x^2}{k^4} - \frac{24}{k^6}\right)$$

Thus Equation (8) can be written

$$y(x) = C_1 \cos kx + C_2 \sin kx + \frac{1}{P}\frac{(M_1 - M_2)x}{l} - M_1 + Q_n(x) \qquad (9)$$

Where values for $Q_n(x)$ are determined as indicated and n is obtained from the application.

CASE I. No Transverse Load, Unequal End Moments, as shown in Fig. 2

$$w = 0,\ M_1 \neq M_2$$

$$y(0) = y(l) = 0$$

Since w equals 0, the generalized solution defined by Equation (8) becomes

$$y(x) = C_1 \cos kx + C_2 \sin kx + \frac{1}{P}\left(\frac{M_1 - M_2}{l}x - M_1\right)$$

Boundary conditions give

$$y(0) = 0,\ \therefore\ C_1 = \frac{M_1}{P}$$

$$y(l) = 0,\ \therefore\ C_2 = \frac{1}{P \sin kl}(M_2 - M_1 \cos kl)$$

$$\therefore\ y = \frac{M_2}{P}\left(\frac{\sin kx}{\sin kl} - \frac{x}{l}\right) + \frac{M_1}{P}\left[\frac{\sin k(l-x)}{\sin kl} - \frac{l-x}{l}\right]$$

CASE II. Beam with one end fixed, other end supported, under axial compression and uniform transverse load, as shown in Fig. 3.

$$n = 0$$

$$y(0) = y(l) = 0$$

$$y'(0) = 0$$

With $n = 0$, and $M_1 = -M_1$

(*Continued on next page*)

Equation (8) becomes

$$y(x) = C_1 \cos kx + C_2 \sin kx + \frac{M_1}{P}\left(1 - \frac{x}{l}\right) + \frac{w}{2P}(x^2 - lx) - \frac{w}{Pk^2}$$

$$y(0) = 0, \therefore C_1 = \frac{w}{Pk^2} - \frac{M_1}{P}$$

$$y(l) = 0,$$

$$\therefore C_2 = \frac{w}{Pk^2 \sin kl} + \left(\frac{M_1}{P} - \frac{w}{Pk^2}\right)\cot kl$$

and the equation of the elastic line becomes

$$y = -\frac{M_1}{P}\left[\frac{\sin k(l-x)}{\sin kl} - \frac{l-x}{l}\right] + \frac{w}{Pk^2}\left[\frac{\sin k(l-x) + \sin kx}{\sin kl} + \frac{k^2(x^2 - lx)}{2} - 1\right]$$

M_1 is determined from the boundary condition that $y'(0)$ equals 0 which gives

$$M_1 = \frac{wl}{k}\left[\frac{\left(\tan\frac{kl}{2} - \frac{kl}{2}\right)\tan kl}{\tan kl - kl}\right]$$

CASE III. Simple beam under axial compression and triangularly distributed load, as shown in Fig. 4

$$n = 1$$
$$y = 0 = y(l) = 0$$

with $n = 1$, Equation (8) becomes

$$y(x) = C_1 \cos kx + C_2 \sin kx + \frac{1}{P}\left[\frac{(M_1 - M_2)}{l}x - M_1\right] + \frac{w}{Pl}\left[\frac{x^3 - l^2 x}{6} - \frac{x}{k^2}\right]$$

$$y(0) = 0, \therefore C_1 = \frac{M_1}{P}$$

$$y(l) = 0,$$

$$\therefore C_2 = \frac{1}{P \sin kl}\left(M_2 + \frac{w}{k^2} - M_1 \cos kl\right)$$

and equation of the elastic line becomes

$$y(x) = \frac{M_1}{P}\left[\frac{\sin k(l-x)}{\sin kl} - \frac{l-x}{l}\right] + \frac{M_2}{P}\left(\frac{\sin kx}{\sin kl} - \frac{x}{l}\right) + \frac{w}{P}\left(\frac{\sin kx}{k^2 \sin kl} + \frac{x^3 - l^2 x}{6l} - \frac{x}{k^2 l}\right)$$

CASE III (A). Beam with one end fixed, other end supported, under axial compression and triangularly distributed load, as shown in Fig. 5.

$$M_2 = 0$$
$$M_1 = -M_1$$
$$y'(0) = 0$$

Substituting M_2 equals 0, M_1 equals $-M_1$, in the preceding solution

$$y(x) = -\frac{M_1}{P}\left[\frac{\sin k(l-x)}{\sin kl} - \frac{l-x}{l}\right] + \frac{w}{P}\left[\frac{\sin kx}{k^2 \sin kl} + \frac{x^3 - lx}{6l} - \frac{x}{k^2 l}\right]$$

Condition $y'(0)$ equals 0 gives

$$M_1 = \frac{wl}{k}\left(\frac{\csc kl - \frac{kl}{6}}{1 - kl \cot kl}\right)$$

CASE IV. Simple beam under axial compression and parabolically distributed load, as shown in Fig. 6.

$$n = 4$$
$$y(0) = y(l) = 0$$

with $n = 4$, and $M_1 \neq M_2$. Equation (8) reduces to

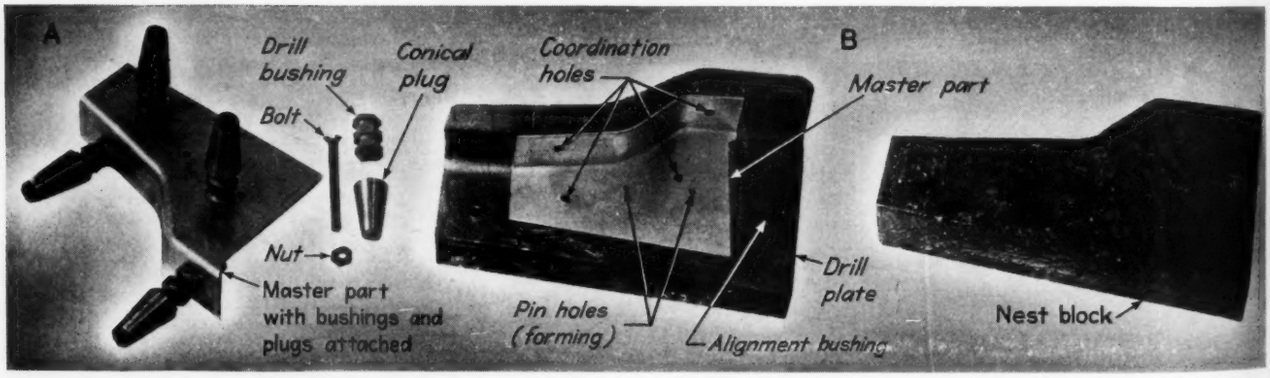
$$y(x) = C_1 \cos kx + C_2 \sin kx + \frac{1}{P}\left[\frac{M_1 - M_2}{l}x - M_1\right] + \frac{w}{Pl^4}\left(\frac{x^5 - x^4}{36} - \frac{x^4}{k^2} + \frac{12x^2}{k^4} - \frac{24}{k^6}\right)$$

$$y(0) = 0, \therefore C_1 = \frac{M_1}{P} - \frac{24w}{Pl^4 k^6}$$

$$y(l) = 0, \therefore C_2 = \frac{M_2}{P \sin kl} + \frac{w}{Pl^4 \sin kl} \times \left(\frac{l^4}{k^2} - \frac{12l^2}{k^4} + \frac{24}{k^6}\right) - \left(\frac{M_1}{P} - \frac{24w}{Pl^4 k^6}\right)\frac{\cos kl}{\sin kl}$$

$$\therefore y(x) = \frac{M_1}{P}\frac{\sin k(l-x)}{\sin kl} + \frac{l-x}{l} + \frac{M_2}{P} \times \left(\frac{\sin kx}{\sin kl} - \frac{x}{l}\right) + \frac{24w}{Pl^4 k^6} \times \left[\frac{\sin k(l-x)}{\sin kl}\right] + \frac{w}{Pl^4}\left\{\left(\frac{l^4}{k^2} - \frac{12l^2}{k^4} + \frac{24}{k^6}\right)\frac{\sin kx}{\sin kl} + \frac{x^5 - l^5 x}{30} - \frac{x^4}{k^2} + \frac{12x^2}{k^4} - \frac{24}{k^6}\right\}$$

Plastics In Aircraft Tooling

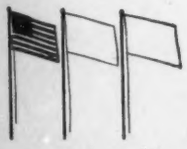


Research and experimentation with both thermosetting and thermoplastic compositions by Lockheed and Vega Aircraft has led to the development of a technique for producing fixtures, former blocks and drill jigs in plastic materials. Drill jigs are made by bolting the drill bushings to the coordination holes of a master part as shown at *A*. The assembly is then placed in a retaining form and a thermoplastic material is poured around the part and the drill bushings. After an oven curing operation to solidify the material in conformity to the contour of the part, the retaining forms and bolts are removed, and the free surface of the block is finished flat in a joiner to within ¼ to $\frac{3}{16}$ in. of the external bushing faces. Holes to the drill bushings are then chamfered. Illustration *B* shows the drill jig in open position. The thermo-plastic material is cast at temperatures ranging from 225 to 325 deg. F., minimum softening point is 200 deg. F. Therefore, it is possible to cast the jig around an aluminum alloy part without damaging the latter. Danger is also avoided of softening the jig by the heat generated in drilling.

Americans Should Know These

FLAG RULES

When the Flag is being raised or lowered or when it passes in a parade, a man removes his hat with his right hand and places it over his heart while standing at attention. A woman, or a hatless man, places the right hand over the heart. Whenever the Star Spangled Banner is played, a civilian stands and faces the music, with right hand or hat over heart, except when the flag is being lowered, on which occasion he faces the flag. The salute is held until the last note of the anthem is played.



1. The Flag should be displayed from sunrise to sunset. It should be hoisted briskly, but lowered slowly and ceremoniously. The Flag should now be displayed every day.

2. When carried in a procession with other flag or flags, the American Flag should be either on the marching right—i.e., the Flag's own right—or when there is a line of other flags, in center front of that line.

3. When displayed with another flag against a wall from crossed staffs, the Flag of the United States should be on the right, the Flag's own right (the observer's left), and its staff should be in front of the other staff.

4. When a number of flags of States or cities or pennants of societies are grouped and displayed from staffs with the Flag of the United States of America, the latter should be at the center or at the highest point of the group.

5. When flags of States or cities or pennants of societies are flown on the same halyard with the Flag of the United States of America, the latter should always be at the peak, except for the official church flag during services. When flown from adjacent masts, the Flag of the United States of America should be hoisted first and lowered last, and should be at the right of the line (observer's left), and should be as high or higher than any other.

6. When flags of two or more nations are displayed, they should be flown from separate masts at the same height and the flags should be of approximately equal size.

7. When the Flag is displayed from a staff projecting horizontally or at an angle from the window sill, balcony, or front of building, the union of the Flag should go clear to the peak unless the Flag is at half-mast.

8. When the Flag is displayed in a manner other than by being flown from a mast, it should be displayed flat, whether indoors or out. When displayed either horizontally or vertically against a wall, the union should be uppermost or to the Flag's own right, i.e., to the observer's left. In a window it should be displayed with the union or blue field to the left of the observer in the street. When festoons, rosettes, or drapings are desired, bunting of blue, white, and red should be used, but never the Flag.

9. When displayed over the middle of the street, the Flag should be suspended vertically with the union to the north in an east-and-west street or to the east in a north-and-south street.

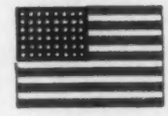
10. On a speaker's platform, the Flag, if displayed flat, should be above and behind the speaker. If flown from a staff it should be in the position of honor, at the speaker's right. It should never cover the speaker's desk or drape over the front of the platform, but bunting may be used for this purpose, if desired, with the blue uppermost.

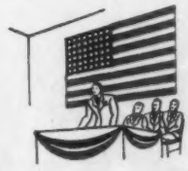
11. When used in unveiling a statue or monument, the Flag should not be allowed to fall to the ground, but should be carried aloft to wave out, forming a distinctive feature during the rest of the ceremony. No object may be placed on the Flag except the Holy Bible.

12. When flown at half-mast, to indicate mourning, the Flag should be hoisted to the peak for an instant and then lowered to the half-mast position; but before lowering the Flag for the day it should be raised again to the peak. Half-mast is one-half the distance between the top and bottom of a mast, the Flag's own width below the peak on a pole or staff.

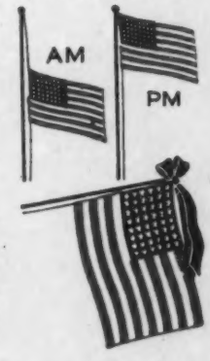
13. When the Flag is displayed on a small staff, as when carried in a parade, mourning is indicated by attaching two streamers of black crepe to the spearhead, allowing the streamers to fall naturally. Crepe is used on a flagstaff only by order of the President.

14. Old, frayed or discolored Flags should be destroyed by private burning, or by some other method in harmony with the reverence and respect we owe to the emblem of our country.





MEMORIAL DAY



The front cover of this issue carries, for the first time in our history, a full-color reproduction of Old Glory, your flag and ours. Americans respect and love it as a matter of course. But that respect is usually expressed casually and without much regard for the rules. We Americans are normally too easily embarrassed to show our true feelings.

Yet, the Stars and Stripes is symbolic of our very freedom, and as such should have our deepest and most intelligent respect—particularly now. It is for this reason that we present, on the preceding page, the Flag Code, based on that adopted by the Second National Flag Conference in Washington, May 15, 1924.

Reprints, on this same stock, suitable for framing or posting, will be sent you free on request.

WHAT'S A FLAG?

WHAT'S A FLAG? What's the love of country for which it stands? Maybe it begins with love of the land itself. It is the fog rolling in with the tide at Eastport, or through the Golden Gate and among the towers of the Green, throwing a shining glory on Lake Champlain and above the Adirondacks. It is the storied Mississippi rolling swift and muddy past St. Louis, rolling past Cairo, pouring down past the levees of New Orleans. It is lazy noon-tide in the pines of Carolina, it is a sea of wheat rippling in Western Kansas, it is the San Francisco peaks far north across the glowing nakedness of Arizona, it is the Grand Canyon and a little stream coming down out of a New England ridge, in which are trout.

It is men at work. It is the storm-tossed fishermen coming into Gloucester and Provincetown and Astoria. It is the farmer riding his great machine in the dust of harvest, the dairyman going to the barn before sunrise, the lineman mending the broken wire, the miner drilling for the blast. It is the servants of fire in the murky splendor of Pittsburgh, between the Allegheny and the Monongahela, the trucks rumbling through the night, the locomotive engineer bringing the train in on time, the pilot in the clouds, the riveter running along the beam a hundred feet in air. It is the clerk in the office, the housewife doing the dishes and sending the children off to school. It is the teacher, doctor and parson tending and helping, body and soul, for small reward.

It is the small things remembered, the little corners of the land, the houses, the people that each one loves. We love our country because there was a little tree on a hill, and grass thereon, and a sweet valley below; because the hurdy-gurdy man came along a sunny morning in a city street; because a beach or a farm or a lane or a house that might not seem much to others were once, for each of us, made magic. It is voices that are remembered only, no longer heard. It is parents, friends, the lazy chat of street and store and office, and the ease of mind that makes life tranquil. It is Summer and Winter, rain and sun and storm. These are flesh of our flesh, bone of our bone, blood of our blood, a lasting part of what we are, each of us and all of us together.

It is the stories told. It is the Pilgrims dying in their first dreadful winter. It is the minute man standing his ground at Concord Bridge, and dying there. It is the army in rags, sick, freezing, starving at Valley Forge. It is the wagons and the men on foot going westward over Cumberland Gap, floating down the great rivers, rolling over the great plains. It is the settler hacking fiercely at the primeval forest on his new, his own lands. It is Thoreau at Walden Pond, Lincoln at Cooper Union, and Lee riding home from Appomattox. It is corruption and disgrace, answered always by men who would not let their flag lie in the dust, who have stood up in every generation to fight for the old ideals and the old rights, at risk of ruin or of life itself.

It is a great multitude of people on pilgrimage, common and ordinary people, charged with the usual human failings, yet filled with such a hope as never caught the imaginations and the hearts of any nation on earth before. The hope of liberty. The hope of justice. The hope of a land, in which a man can stand straight, without fear, without rancor.

The land and the people and the flag—the land a continent, the people of every race, the flag a symbol of what humanity may aspire to when the wars are over and the barriers are down; to these each generation must be dedicated and consecrated anew, to defend with life itself, if need be, but, above all, in friendliness, in hope, in courage, to *live* for.

—*The New York Times,* June 14, 1940.

Materials Section

COBALT ALLOY MAGNETS

Cobalt is a critical element in permanent magnets. Since the bulk of world output of cobalt has been produced in Africa, present domestic consumption must be conserved by redesign of magnets and substitution wherever possible. Use of other critical materials as substitutes is justified in consideration of quantities involved. Most attention, however, should be given to non-strategic molybdenum, which is available in large quantity.

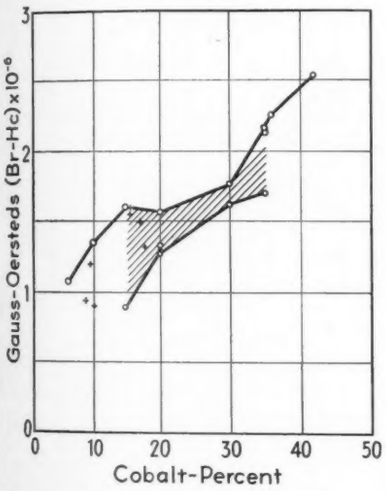


Fig. 1—Magnetic performance of iron-carbon alloys as affected by cobalt content. Crosses show relative performance of several complex steels

SUMMARY OF SUBSTITUTES

1. Substitutes for ordinary commercial low-cobalt magnet steel and chromium-cobalt magnet steel are molybdenum and tungsten-chromium-molybdenum dispersion-hardened alloys containing no cobalt. Little or no change in magnet design is required.

2. Nickel-aluminum alloys with no cobalt can replace these steels also where magnet design permits casting the finished shape. Up to 5 percent cobalt might be contained in such alloys when replacing chromium-cobalt alloys containing 16 percent cobalt.

3. Probable substitutes for tungsten-cobalt commercial steels containing 17 percent cobalt are precipitation-hardened alloys containing 6 to 10 percent cobalt and 16 to 19 percent molybdenum. In the latter alloy 16 percent molybdenum takes the place of 11 percent cobalt.

4. Possible substitutes for these tungsten-cobalt steels are various iron-nickel-aluminum alloys of the Mishima type with no cobalt.

5. Possible substitutes for 35 to 41 percent cobalt steels, where no machining or mechanical forming is required, can be found among Mishima type alloys.

6. There are few, if any, substitutes for 35 to 41 percent cobalt steels where machining is required. Redesign of such magnets to permit utilization of less cobalt or one of the substitutes might be done in some instances.

7. No substitute for cobalt in extremely high performance alloys of the Alnico and "new KS" types is known.

EVALUATION OF ALLOYS. Ordinary criterion in evaluating permanent magnets is the maximum product of its magnetic flux density B in gausses and the corresponding magnetizing force H in oersteds, or $(BH)_{max.}$. This is a measure of maximum magnetic energy that can be stored in the material. However, since values of remanence, Br, and coercive force, Hc, are more commonly reported and their product is roughly proportional to $(BH)_{max}$, the valves of $(BrHc)$ are the bases of conclusions given here.

Flux density in a fully magnetized

Table I—Low and Medium-Cobalt Magnet Steels

Alloy No.	Analysis, percent						*Br*, gausses	*Hc*, oersteds	(*BrHc*) gauss-oersteds x 10^{-6}
	C	W	Cr	Mn	Mo	Co			
1	0.9–1.2	—	8–11	—	1–1.5	8–11	9,500–7,000	140–165	1.3–1.1
2	0.9–1.2	—	9–11	—	1–1.5	14–17	9,500–7,500	170–200	1.6–1.5
3	1.0	—	5	1.0	—	10	9,000	100	0.9
4	1.0	—	5	2.0	—	20	8,000	160	1.3
5	1.5	8.75	2–2.5	—	—	17	9,000	165	1.5
6a	0.52	8.0	2.2	0.42	—	8.9	9,900	97	0.94
6b	0.52	7.8	1.8	0.57	—	17.8	10,150	130	1.32

a. Other elements: Si, 0.29; P, 0.046; S, 0.058; Ni, 0.51
b. Other elements: Si, 0.25; P, 0.024; S, 0.043; Ni, 0.62

bar is determined by magnet shape. Therefore *BrHc* is not the only necessary criterion. Too high coercive force with too low residual induction may give satisfactory *BrHc* but will not necessarily permit substitution without redesign.

IRON-CARBON ALLOYS. Iron-carbon alloys can be cast, annealed, forged, machined or otherwise shaped mechanically and subsequently hardened and magnetized. Commercial cobalt steels range from a few percent cobalt up to 40 percent and generally carry about 0.9 percent carbon. Fig. 1 shows relative magnet performance of some of these steels as obtained from several investigators.

In the "KS" steels the coercive force and performance product are in general directly proportional to cobalt content, even with the usual impurities. These steels contain 0.4 to 0.8 percent carbon, 30 to 40 percent cobalt, 5 to 9 percent tungsten, and 1.5 to 3.0 percent chromium. Numerous modifications of these steels contain 0.4 to 1.37 percent carbon, 15 to 55 percent cobalt, 3 to 9 percent tungsten, 1.5 to 20 percent chromium, and in some instances, 0 to 4.5 percent molybdenum.

Ordinary non-cobalt permanent magnets are low-alloy chromium or tungsten steels whose low *BrHc* values make them unsuited to replace cobalt magnets. Simple molybdenum steels with up to 4 percent molybdenum perform about the same. Other elements, such as titanium, vanadium, beryllium, and tantalum have not been found to produce any marked increase in performance when alloyed with plain carbon steels.

Various complex steels afford some conservation of cobalt. A steel containing 10 percent chromium, 15 percent cobalt, and 0.9 percent carbon is nearly equivalent in *BrHc* value to a 30-percent plain cobalt steel.

Crosses in Fig. 1 show the performance of several such steels tabulated in Table 1. Substitution of low or medium-cobalt alloy steels will require redesign of magnets if relation between *Br* and *Hc* varies too much from that relation in the original steel. Other considerations, such as castability, workability and hardenability also influence choice of steel.

PRECIPITATION - HARDENING ALLOYS. Precipitation-hardened magnet alloys are the highest-performance magnetic alloys known. They contain negligible carbon and are rendered magnetic by aging at elevated temperature. Brittleness of some of these alloys is often detrimental because they cannot be forged or machined. Such alloys are

Table II—Dispersion Hardening Magnetic Alloy Steels

No.	Analysis, percent						*Br* gausses	*Hc* oersteds	*BrHc* X 10^{-4} gauss-oersteds
	Co	Ni	Al	W	Cr	Other Elements			
1	—	25.0	5.0	—	—	—	6,900	100	0.7
2	—	18.0	10.2	—	—	—	9,100	120	1.09
3	—	21.0	12.5	—	—	—	8,000	150	1.20
4	—	25.5	12.4	—	—	—	3,700	330	1.22
5	—	24.5	10.2	—	—	—	9,600	240	2.30
6	—	29.5	12.0	—	—	—	9,400	430	4.04
7	—	16.5	9.8	5.0	—	—	9,200	140	1.3
8	—	17.0	9.5	2.0	—	—	9,700	155	1.5
9	—	25.0	10.2	2.7	—	—	9,650	270	2.6
10	—	29.5	11.5	2.8	—	—	9,500	460	4.37
11	—	18.0	10.0	—	3.0	C 0.1	10,000	172	1.72
12	—	24.8	10.0	—	2.3	C 0.2	9,700	265	2.57
13	—	29.5	12.0	—	3.0	C 0.2	9,600	500	4.80
14	—	24.5	10.0	—	—	Mo 0.5	9,600	290	2.78
15	—	23.0	10.0	—	—	Mo 5.0	9,400	300	2.82
16	—	28.5	12.0	—	—	Mo 2.0	9,500	490	4.65
17	—	32.0	12.0	—	—	Ti 1.–2.0	4,300	600	2.58
18	—	32.0	12.0	—	—	Ti 0.5, Si 0.6	5,200	700	3.64
19	—	—	—	18.45	—		10,900	70	0.76
21	—	—	—	27.9	—	—	8,000	110	0.88
22	—	—	—	30.0	10.0	—	7,000	120	0.84
24	—	—	—	25.0	15.0	—	7,000	180	1.26
25	—	—	—	25.0	15.0	Mo 5.0	5,000	200	1.00
26	—	—	—	16.0	7.0	Mo 10.0	6,500	260	1.69
27	—	—	—	26.0	7.0	Mo 9.0	8,000	215	1.73
28	—	—	—	—	—	Mo 13.0	10,500	65	0.65
30	—	—	—	—	—	Mo 19.0	8,200	165	1.34
31	—	—	—	—	—	Mo 23.4	7,000	219	1.26
32	—	—	—	—	13.0	Mo 15.0	8,500	100	0.85
33	—	—	—	—	17.5	Mo 15.0	7,000	145	1.02
34	—	—	—	—	7.5	Mo 21.0	5,300	330	1.75
36	—	—	—	—	—	Pt 77.8	5,830	1,570	9.15
37	—	—	—	—	—	Pt 72.7 Rh 4.2	3,700	1,400	5.19
38	5.0	17.0	9.0	—	—	—	9,400	160	1.51
39	30.0	12.4	7.0	—	—	—	9,500	180	1.71
41	5.0	24.8	10.2	—	—	—	9,800	290	2.84
42	5.0	20.0	12.0	—	—	—	7,750	460	3.57
44	4.5	12.0	29.5	—	—	—	9,600	510	4.90
45	10.0	16.0	9.0	—	2.5	—	10,000	195	1.95
46	20.0	14.0	8.0	—	2.5	—	10,000	200	2.00
47	6.0	24.0	9.0	—	2.0	—	9,800	290	2.84
48	5.0	29.5	10.0	—	2.5	—	9,500	520	4.94
49	30.0	—	—	15.0	—	—	9,000	90	0.81
50	49.9	—	—	30.0	—	—	4,200	250	1.12
51	24.0	—	—	27.7	—	—	9,600	148.6	1.42
52	15.0	—	—	18.0	—	—	11,500	145	1.68
53	12.0	—	—	—	—	Mo 10.0	13,000	70	0.91
54	10.0	—	—	—	—	Mo 13.0	11,100	135	1.50
55	6.0	—	—	—	—	Mo 16.0	9,900	170	1.68
56	12.0	—	—	—	—	Mo 13.0	11,300	150	1.70
57	10.0	—	—	—	—	Mo 16.0	10,000	205	2.05
58	6.0	—	—	—	—	Mo 19.0	8,300	245	2.04
59	12.0	—	—	—	—	Mo 19.0	8,400	300	2.52
60	20.0	10.0	—	—	—	Ti 10.0	9,000	250	2.26
62	28.0	16.0	—	—	—	Ti 11.0	7,500	830	6.24
63	24.3	13.6	4.5	—	—	Ti 12.8	7,200	750	5.40
64	24.5	13.8	—	3.5	—	Ti 12.9	7,200	700	5.05
65	23.9	13.4	—	—	—	Cu 6.7, Ti 12.6	6,300	870	5.48
66	24.5	13.8	—	—	—	Mn 3.5, Ti 12.9	8,100	750	6.08
67	24.5	13.8	—	—	—	Ag 3.5, Ti 12.9	8,250	780	6.44
68	23.3	—	—	—	—	Pt 76.7	4,530	2,650	12.0
69	21.0	14.0	8.0	—	—	Cu 3.0	12,500	560	7.0

Table III—Commercial Cobalt Magnet Steels*

Alloy No.	Nominal Composition, percent						*Br* gausses	*Hc* oersteds	(*BrHc*) X 10^{-6} gauss-oersteds
	Co	W	Cr	Mo	Mn	C			
1	8.50	1.25	4.75	—	0.35	0.9	7,500	120	0.90
2	16.0	—	9.00	1.30	0.3	0.95	8,000	180	1.44
3	17.0	8.75	2.0–5.0	—	0.5	0.85	9,000	165	1.49
4	35–41	3.75–7.00	3.5–5.75	—	0.3–0.85	0.9	9,700	235	2.28

* *Scott, K. L., Metals Handbook: Am. Soc. Metals, 1939, p. 502.*

Table IV—Possible Substitutes for 8.5-percent Cobalt Steel

Table No.	Alloy No.	Composition, percent Fe = remainder + usual impurities							Hardening temp., F.	*Br* gausses	*Hc* oersteds	(*BrHc*) X 10^{-6} gauss-oersteds
		Co	Ni	Al	W	Cr	Mo	C				
III	1	8.5	—	—	1.25	4.75	—	0.9	1,640	7,500	120	0.9
II	31	—	—	—	—	—	23.4	—	1,190	7,000	219	1.26
		—	—	—	—	—	23.4	—	1,130	7,500	120	0.9
II	21	—	—	—	27.9	—	—	—	1,290	8,000	110	0.88
II	27	—	—	—	26.0	7.0	9.0	—	1,290	8,000	215	1.73
		—	—	—	26.0	7.0	9.0		1,180	7,500	120	0.9
II	22	—	—	—	30.0	10.0	—	—	1,250	7,000	120	0.84
		—	—	—	30.0	10.0	—	—	1,290	7,000	125	0.88
II	24	—	—	—	25.0	15.0	—	—	1,290	7,000	180	1.26
		—	—	—	25.0	15.0	—	—	1,190	7,000	130	0.91
II	3	—	21.0	12.5	—	—	—	—	1,290	8,000	150	1.20
		—	21.0	12.5	—	—	—	—	1,250	7,500	120	0.9

Table V—Possible Substitutes for Commercial Cobalt-Chromium Magnet Steel

Table No.	Alloy No.	Composition, percent Fe = remainder + usual impurities							Hardening temp., F.	*Br* gausses	*Hc* oersteds	(*BrHc*) X 10^{-6} gauss-oersteds
		Co	Ni	Al	W	Cr	Mo	C				
iII	2	16.0	—	—	—	9.0	1.3	0.95	*	8,000	180	1.44
II	27	—	—	—	26.0	7.0	9.0	—	1,290	8,000	215	1.73
					26.0	7.0	9.0	—	1,250	8,000	180	1.44
II	31	—	—	—	—	—	23.4	—	1,190	7,000	219	1.26
							23.4		1,180	7,500	190	1.43
II	30	—	—	—	—	—	19.0	—	—	8,200	165	1.35
II	8	—	17.0	9.5	2.0	—	—	—	—	9,700	155	1.50
II	38	5.0	17.0	9.0	—	—	—	—	—	9,400	160	1.51

* Triple heat-treatment: 2,100 deg. F., cool in air, 1,150 deg. F., cool in air, 1,830 deg. F., cool in air.

Table VI—Possible Substitutes for Commercial Cobalt-Tungsten Magnet Steels

Table No.	Alloy No.	Composition, percent Fe = remainder + usual impurities							Hardening temp., F.	*Br* gausses	*Hc* oersteds	(*BrHc*) X 10^{-6} gauss-oersteds
		Co	Ni	Al	W	Cr	Mo	C				
III	3	17.0	—	—	8.75	2.0–5.0	—	0.85	1,740	9,000	165	1.49
II	5	—	24.5	10.2	—	—	—	—	—	9,600	240	2.30
II	8	—	17.0	9.5	2.0	—	—	—	—	9,700	155	1.5
II	9	—	25.0	10.2	2.7	—	—	—	—	9,650	270	2.6
II	11	—	18.0	10.0	—	3.0	—	—	—	10,000	172	1.72
II	38	5.0	17.0	9.0	—	—	—	—	—	9,100	160	1.51
II	55	6.0	—	—	—	—	16.0	—	—	9,900	170	1.68
II	57	10.0	—	—	—	—	16.0	—	—	10,000	205	2.05

used where magnet designs permit casting the final magnet shapes. Powder metallurgy can be employed in fabrication, particularly small pieces and those of intricate shape.

Composition and properties of many of these alloys are given in Table II. Best reported values of *Br* and *Hc* are shown but actual working values of many can be varied over wide limits, depending upon heat-treatment. The few commercially available standard magnetic cobalt alloys in Table III are the ones that must be replaced if there is an extreme shortage.

The platinum alloys have the highest *BrHc* values but, of course, are not economic substitutes. They also are not satisfactorily appraised by the values in Table II. Alloy 69 is much superior to alloy 68 or any of the platinum alloys. The $BH_{max.}$ of alloy 68 is 3,770,000 as compared with 4,500,000 to 5,000,000 for alloy 69.

SUBSTITUTES FOR PRECIPITATION-HARDENED ALLOYS. Using one of the ordinary commercial magnet steels of Table III as a standard, Tables IV, V, and VI show possible substitutions. Variations of magnetic properties brought about by variations in aging temperature, as interpolated from published curves, are indicated in some instances.

Inspection of Table IV reveals that acceptable substitutes containing no cobalt can be had for low-cobalt magnet steels. Insofar as magnetic properties are concerned, the molybdenum alloy 31, the tungsten-chromium-molybdenum alloy 27, and the nickel-aluminum alloy 3, properly heat-treated, can be substituted directly. The 23.4-percent molybdenum steel can be forged at 2,000 deg. F. The working must be done before hardening. Probably all of the alloys in Table IV except No. 3, can be worked before hardening. Alloys 22 and 24 approach the cobalt steel closely enough to be considered possible substitutes with slight changes in magnet designs.

Inspection of Table V shows that after proper heat-treatment 23.4-percent molybdenum and the 26–7–9 tungsten-chromium-molybdenum alloys can replace the 16-percent cobalt steel. The same general considerations apply as in Table IV. The Mishima alloys 8 and 38 are brittle but can be cast.

It is more difficult to find forgeable magnetic alloy substitutes for cobalt-tungsten steel containing 17 percent cobalt because remanence values are generally lower than 9,000 gausses. Magnets now made in such shape that they can be cast and used without the necessity of forging or drastic machining can be made from the Mishima-type alloys, 5, 8, 9 and 11 in Table VI. Various heat-treatments of these may produce magnetic properties close enough to those of cobalt-tungsten steel to minimize redesigning.

Substitutes for high-cobalt magnet steels are still more difficult to find. Several Mishima, Alnico and "new Honda KS" types have equal or better magnetic properties but are brittle and can only replace shapes that are cast or pressed and sintered. Most of Table II are alloys of this class. There is little possibility of direct substitution of these brittle alloys for 35–41 percent cobalt steel in magnets of intricate or accurately dimensioned shapes, obtainable only by mechanical work, without considerable change in established production routine preceded by experimental development.

The extremely high performance magnet alloys of the Honda "new KS" types, Nos. 60 to 67 in Table II have the highest magnetic performance values of any materials with commercial possibilities. These alloys still contain considerable cobalt, however, and there does not appear to be any known substitute. Some of the iron-nickel-aluminum alloys approach them in performance but are not quite as good.

OXIDE MAGNETS. Oxide magnets are made from metal oxide powders pressed into desired shapes and subsequently sintered. Their remanence values are generally low but coercive forces up to 750 oersteds may be obtained. Magnets made from Fe_3O_4 and $CoFe_2O_4$ pressed sintered at 1,800 deg. F., magnetized at 570 deg. F. and then allowed to cool to room temperature have *Br* values of 3,000 to 5,000 gausses and *Hc* values of 600 to 400 oersteds. Chromium, zinc, tungsten, nickel, and copper oxides have been used in oxide magnets.

Oxide magnets have rather low density, which accounts in part for their low remanence, but their performance is comparatively high. $BH_{max.}$ up to 1.3×10^6 gauss-oersteds are reported by P. H. Brace, Westinghouse company. This is equivalent to about 3.2×10^6 for *BrHc*. This type of magnet is not extensively used.

SOFT MAGNETIC ALLOYS. Although it seems possible to substitute for at least part of the cobalt-containing "Perminvar" alloys, there is a high saturation, low loss alloy containing 49 percent cobalt for which no equivalent is known. Cobalt is used in these alloys where constant magnetic permeability at low magnetic forces is necessary, such as in coil cores for radio and telephone circuits where constant reactance is essential. Perminvar contains 20 to 75 percent nickel and 5 to 40 percent cobalt.

Results similar to those from Perminvar are described in the "A.S.M. Metals Handbook," 1939, p. 496, with 50 percent iron-nickel alloys. Reference is made also to constant permeability alloys containing 35 to 55 percent nickel, 45 to 50 percent iron, and 5 to 15 percent copper.

[EDITOR'S NOTE: The above data are condensed from a portion of a report prepared by John Koster and H. W. Davis, Bureau of Mines, for the Office of Production Management through the Advisory Committee on Metals and Minerals of the National Academy of Sciences and National Research Council.]

Table VII—Relative Efficiency of Cobalt Utilization in Magnetic Alloys

Obtained by dividing *BrHc* values by percent cobalt content. Alloy No. 42 uses cobalt most efficiently of all metals listed, No. 51 least effectively. Cobalt's effectiveness in the oxide magnet is about the same as in low-cobalt steels.

Table No.	Alloy No.	Types or class of alloy	Co, percent	(*BrHc*) X 10^{-6} gauss-oersteds	*BrHc* X 10^{-4} Percent Co
III	1	Commercial steel: low cobalt	8.5	0.9	106
III	2	Commercial steel: Co-Cr	16.0	1.44	90
III	3	Commercial steel: Co-W	17.0	1.49	88
III	4	Commercial steel: 35 to 41 percent Co	38.0	2.28	60
II	38	Mishima: 17 percent Ni; 9 percent Al	5.0	1.51	300
II	42	Alnico: 20 percent Ni; 12 percent Al	5.0	3.57	712
II	51	24 percent Co, 28 percent W, dispersion-hardened	24.0	1.42	59
II	58	6 percent Co, 19 percent Mo, dispersion-hardened	6.0	2.04	340
II	59	12 percent Co, 19 percent Mo, dispersion-hardened	12.0	2.52	210
II	62	Honda "new KS": 16 percent Ni; 11 percent Ti	28.0	6.24	222
Oxide		Fe_3O_4–$CoFe_2O_4$; 1:1 by weight	12.5	1.35	108

TINLESS SOLDERS

So MUCH EVIDENCE IS IN HAND that, by suitable technique, tin-free solder can be used in place of tin-containing solder, its use should be made the rule rather than the exception. Lead-silver solders appear to be the most promising among substitutes suggested so far, but lower melting solders have been tried and found suitable for many purposes. The high melting point of lead-silver solder requires a higher temperature of application. However, once the technique of applying lead-silver solder is understood and adopted, its cheapness and availability are likely to make this solder standard material. Properly made lead-silver joints are stronger and cost less than those of lead-tin. In appearance, the lead-silver solder is dark like lead, rather than bright like tin or lead-tin solder.

LOW-MELTING SOLDERS

Several substitute low-melting solders have been tried out in the hope of avoiding differences in the technique of applying solder. One of the best of these contains 90 percent lead, 8 percent cadmium, and 2 percent zinc, or slight modifications of this composition. This solder resembles lead-tin in ease of application and makes good joints. However, the supply of cadmium is too limited to permit its extensive use.

Other suggestions have been for bismuth-containing solders, such as that containing 80 percent lead, 15 percent bismuth, and 5 percent antimony, and for "intermediate" solders containing a smaller tin content than lead-tin solder, with some tin replaced by silver, and bismuth added to pull down the melting point. Some of these have the following percentage analyses:

75 Pb, 20 Sn, 3 Bi, 1.5 Ag, 0.5 Sb with about 0.1 Cu
85 Pb, 10 Sn, 3 Bi, 1.5 Ag, 0.5 Sb with about 0.1 Cu
78.5 Pb, 15 Sn, 5 Bi, 1.5 Ag

Others leave out bismuth and are intermediate between lead-tin and lead-silver:

87.75 Pb, 10 Sn, 2.25 Ag

CONDITIONS OF USE. Where pressure can be kept on a joint as it freezes, or where the joint can be chilled rapidly, or where some splitting of the joint can be tolerated, long-freezing-range substitute solders may have application. None of the low-melting solders except that containing cadmium appear satisfactory for high speed automatic soldering side seams of can bodies, which is one of the most difficult of soldering tasks.

In spite of a fairly good appearance and satisfactory bursting tests (which measure the locking effect of a seam more than the strength of the soldered joint), joints made with these solders proved to be imperfect through "hot brittleness." The solder joint pulled itself apart into two layers on freezing because of contraction stresses acting while the interior was still pasty.

In other applications where the metal to be joined will not stand the higher temperature at which the lead-silver solder must be applied, the faults of the long-freezing-range solders may have to be tolerated, or overcome in one way or another. Means are available, however, for raising the recrystallization temperature of copper or brass to permit higher dip-soldering temperatures.

LEAD-SILVER SOLDERS

For many purposes, the 97.5 lead, 2.5 silver solder appears the most suitable composition. Slight reduction of silver, and inclusion of a little antimony and perhaps a trace of phosphorus has been suggested. Solder of this type is usable for some purposes. A solder long used in the electrical industry contains 97.25 lead, 2.5 silver, and 0.25 copper, and may be an improvement for soldering copper. Addition of either copper or antimony appears detrimental or at least not desirable for soldering tinned surfaces, on the information now at hand.

The 97.5 lead, 2.5 silver composition is close to the eutectic, so that the solder freezes sharply at its melting point. To produce a slight freezing range the silver may be raised to 5 or 6 percent, as specified in S.A.E. Aircraft Materials Specification 4755 for dipping solder. Increase in silver increases the strength of the joint, but latest information is that over 4 percent silver will seldom, if ever, be justified.

An outstanding improvement in lead-silver solders is their improved creep resistance, shown in the accompanying table. Decrease in spreading properties is considered not essential in making sound joints.

An optimum solder thickness of 0.005 in. for maximum strength joints is reported by F. N. Rhines and W. A. Anderson, Carnegie Institute of Technology. With this thickness they obtained tensile strengths of 11,500 lb. per sq. in. for 97 Pb, 2.5 Ag, 0.25 Cu solder; 9,100 lb. per sq. in. for 95 Pb, 5 Ag solder; and 9,560 lb. per sq. in. for 98 Pb, 2 Ag solder. Shear strengths were 4,770, 4,100 and 4,420 lb. per sq. in. respectively.

FLUXING. Beside the higher melting point, about 580 deg. F., and the higher temperature of application, say 675 to 775 deg. F., lead-silver solder requires active fluxing. Zinc chloride is an effective flux, particularly so when, as in dip soldering, it can be used in the fused condition, as a layer over the molten solder. The flux is washed from the finished joint with dilute (1 or 2 percent) hydrochloride acid, followed in turn by water, dilute sodium carbonate to neutralize the last traces of acid, and water.

This procedure is required since zinc chloride leaves residues that are difficultly soluble in water and remain on the work to produce corrosion trouble later. Results are as good as with dipping solders. Rosin is not satisfactory as a flux, and the organic amines that are effective non-corrosive fluxes for lead-tin and lead-cadmium-zinc solders are too strongly decomposed at the necessary temperature.

CLEAN SURFACES. Lead-silver solder itself, as well as the metal to be soldered, must have a clean surface. Do not depend upon the flux to clean the joint. Such methods as acid pickling, grit blasting, or cleaning with emery paper should be used.

A useful means of avoiding surface oxidation in using high-lead solders is offered by the Lamp Department of General Electric Company. This practice involves the use of small pointed gas fires which heat both the work and the solder at points of soldering. Natu-

ral gas fires do not produce satisfactory spreading but by adding hydrogen to the gas-air mixture satisfactory results have been obtained.

This practice has been successful with both 97.25 lead, 2.5 silver, 0.25 copper solder and 95 lead, 5 tin solder. Since most artificial gas contains hydrogen, flames can be adjusted so that some of the high lead soldiers will spread. For proper control of spreading, burners should be equipped with valves to adjust the flow of gas, hydrogen and air separately.

CORROSION. Under ordinary conditions lead-silver solder appears to be a corrosion-resistant material. Under unusual conditions it may corrode, for the presence of silver may set up an electrolytic couple. In the presence of moisture or in contact with some organic materials, these high-lead alloys may be subject to chemical attack.

Reports on corrosion are contradictory but the majority opinions of experienced users in mechanical applications are that corrosion is of minor importance. It is known that some impurities, notably magnesium, induce rapid disintegration of lead. On the other hand lead containing something under 1 percent silver is used for anodes in electrolytic zinc manufacture because of their great resistance to corrosion.

Use of 94 Pb, 6 Ag dipping solders for radiators of aircraft engines cooled with ethylene glycol was discontinued because of some corrosion after two or three years service but reversion to this alloy is being studied and the indications are that its corrosion resistance is adequate.

If corrosion conditions of service are such that the lead-silver solders are not sufficiently corrosion resistant, then modified compositions will be necessary. While it is almost pure speculation, in the absence of adequate corrosion tests and service experience, it is not unreasonable to expect that small tin additions of less than 10 percent to the lead-silver solders may materially improve corrosion resistance. A low-tin approach to the "intermediate" type of solder might have some virtue even where there is no real necessity for lowering the melting point.

Table I—Some Properties of Soft Solders

S. Turkus and A. A. Smith Jr., American Smelting and Refining Company

Pb	Sn	Ag	Bi	Sb	Tensile strength lb. per sq. in.	Bond* strength of lapped joints lb. per sq. in.	Spread* of ½ gr. in sq. in.	Creep rate† in percent per year at 86 deg. F. (lb. per sq. in.) 200	400	600	800
60	40	....	....	....	5,660	6,270	1.30	10.9	92.0	300	....
97.5	....	2.5	....	....	4,980	3,740	0.19	0.10	0.15	....	0.50
95	....	5.0	....	....	4,915	4,340	0.20	0.18	0.22	....	0.45
90	10	....	....	....	4,850	4,960	0.27	2.5	12.0	....	....
87.75	10	2.25	....	....	4,950	5,000	0.41	....	2.3	8.0	....
80	20	....	....	....	4,940	5,680	0.37	6.7	18.7	....	....
78	20	2.0	....	....	5,620	5,550	0.57	....	....	....	....
70	30	....	....	....	5,390	5,770	0.83	10.0	50.0	....	....
69	30	1.0	....	....	8,810	5,620	0.86	....	4.0	20.0	....
78.5	15	1.5	5	....	4,960	5,310	0.47	....	....	....	....
77.5	15	1.5	5	1.0	8,000	5,090	0.29	....	....	....	....
74.85	20	1.5	3	0.5	8,120	5,380	0.39	....	....	....	....

* Tests made on copper sheet † Tests made on chill cast strips

BLACK PLATE SOLDERING

Until the technique for using tinless solder on black plate has been developed, the use of lead-tin solder in order to permit untinned can bodies should not be barred. Soldering these with lead-silver is not yet commercially feasible, though there is no in inherent reason why it cannot be worked out by proper attention to such features as mechanical cleaning, active fluxing, deposition on the parts to be joined.

Active study of soldering black plate is urgently needed since improvements in lacquer coatings over tin-free "black plate" that has been given a bonderizing or analogous coating, are rapidly extending the range of applicability of tin-free can stock.

WELDING AND BRAZING

Welding is a possible substitute for soldering and would solve the can makers' problem except that welding methods are not yet developed to give the speed that is possible with solder and would require extensive modifications of equipment.

So-called hydrogen-copper brazing should be given consideration for joining steel with copper and copper with brass. This includes the use of other reducing atmospheres as well as pure hydrogen. One instance of substitution of brazing for soldering which saves 4 tons of tin annually is in wire connections on Westinghouse motors.

WIPING SOLDER

Lead-burning technique can be applied so as to avoid entirely the use of wiping solder by plumbers and linesmen who join cables, sheathes, etc. Many workmen who are experienced in lead-burning technique prefer it to wiping solder.

JOINT DESIGN

Lap joints only, not butt joints should be soldered. For mechanical joints the area in shear should be calculated on the basis of shear strength of the solder. For electrical joints the lap depends upon thickness of strips. A ½-in. lap or more should be used for strips up to $\frac{1}{16}$ in. thick. A clip around the joint should be added for strips more than $\frac{1}{16}$ in. thick. The length inserted into a terminal should not be less than twice the diameter of the cable.

Clearances of 0.001 to 0.010 in. are permissible but best strength and ease of soldering are obtained with about 0.003-in. clearance.

[EDITOR'S NOTE: This material is taken largely from Report No. 45 to the War Production Board, prepared by Dr. H. W. Gillett, Battelle Memorial Institute.]

SPRING STEELS

H. CARLSON
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Selection of domestic steels, as a material for springs, to replace Swedish steels of equivalent wire sizes should be based on lower tensile strength and shorter fatigue life, since Swedish steels are more uniform in quality and can be more highly stressed. Silicon-chromium spring steel alloy, however, has much promise as an alternate. Tests indicate that this alloy will surpass any existing material for springs subjected to high stresses. This alloy steel can be heat-treated to higher Rockwells and higher tensile strength can be developed than with any other spring steel analysis.

TENSILE STRENGTHS OF AMERICAN STEELS are about 10 percent lower than for Swedish steels, especially in the range of wire sizes under $\frac{3}{16}$-in. dia. The fatigue life of American steels, assuming no flaws, is 20 percent less than that of Swedish steel.

These performance differences are not caused primarily by differences in chemical composition. Table I compares chemical compositions of two grades of Swedish steels and two standard specifications for American steels. Swedish steels in general contain less sulphur and phosphorus, but it is possible to obtain American steels within the range of A.S.T.M. A228-41 which have the same chemical compositions as Swedish steels.

Since Swedish steels in wire diameters up to $\frac{3}{16}$ in. and in thin strips possess excellent physical properties, many American manufacturers formerly purchased Swedish rods or bars that had been drawn to about ¼ in. dia., or bars that had been rolled down to about 1 in. wide and $\frac{1}{16}$ in. thick, and finished the drawing or rolling operations in their own plant. For larger sizes over ½ in., American steels are generally as good as Swedish, and in most applications of sizes down to $\frac{3}{16}$ in., either Swedish or American steels can be used with equal success.

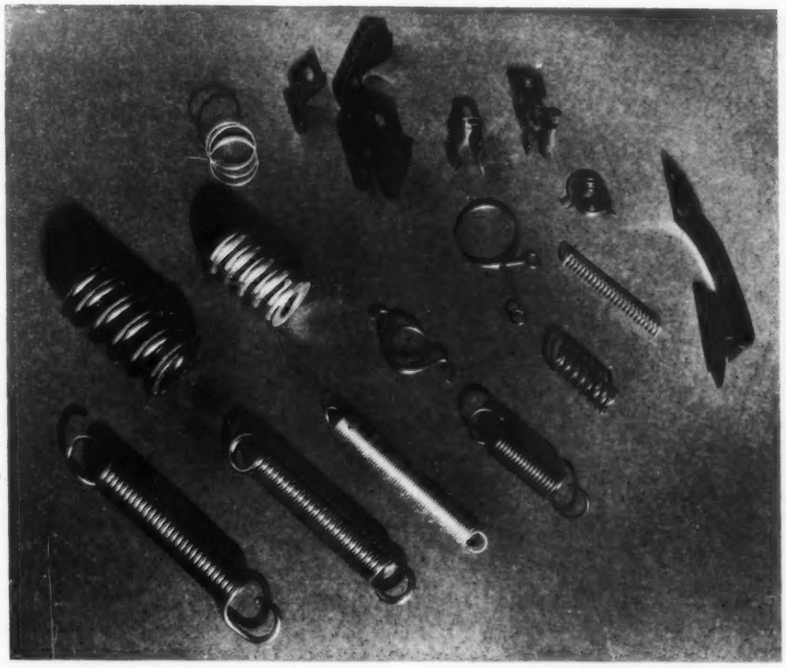

Fig. 1—American steels have been successfully substituted in these springs

Table I—Compositions of Swedish and American Music Wire

Composition	Swedish Steels		American Steels	
	Special No. 1	Special No. 2	S.A.E. 1085	A.S.T.M. A228–41
Carbon	0.80–0.90	0.85–0.95	0.80–0.95	0.70–1.00
Manganese	0.25–0.35	0.25–0.45	0.60–0.90	0.20–0.60
Silicon	0.15–0.25	0.15–0.30	.....	0.12–0.30
Phosphorus	0.025 max.	0.025 max.	0.040 max.	0.030 max.
Sulphur	0.025 max.	0.025 max.	0.055 max.	0.030 max.

SELECTING AMERICAN STEELS

First principle in selecting an American substitute for Swedish spring steel is to choose a standard American specification the chemical composition of which is as close as possible to the Swedish material. Recommended alternates for principal Swedish steels are:

1. Swedish music wire. Until about a year ago, practically all music wire has been made from Swedish steel. Substitute material is American music wire made of S.A.E. 1080, S.A.E. 1085, S.A.E. 1090, or A.S.T.M. A228-41. Chemical composition is usually the same, but the American steel may contain slightly more phosphorus and sulphur. Ultimate tensile strength of American music wire is about 10 percent lower than the Swedish music wire. For complete description of this steel,

see "Spring Steels—II," by Harold Carlson. PRODUCT ENGINEERING, Feb. 1942.

2. Swedish oil-tempered wire (carbon 0.65–0.75 percent). This is a straight carbon steel wire that is a good general purpose spring steel. Substitute is the similar S.A.E. X1065, which most spring companies now use.

3. Swedish oil-tempered wire (carbon 0.75–0.85 percent). Considerations here are same as for above, but best substitute is S.A.E. 1080.

4. Swedish valve spring wire. Excellent quality wire with smooth finish. For substitute use chromium-vanadium S.A.E. 6150 or American music wire.

5. Swedish die spring wire. Substitute same as for valve spring wire.

6. Flat cold rolled spring steels. These are divided into four classes, based upon carbon content application and stress. In the following descriptions, tensile strength figures are for quick comparison only, and are based upon material of equivalent size;

(a) Carbon 0.70–0.80 percent; manganese 0.30–0.50 percent. This material is for general purpose springs not subject to high stress, such as spring clips, locks and spring washers. Comparative tensile strength is approximately 200,000 lb. per sq. in.

(b) Carbon 0.80–0.90 percent; manganese 0.30–0.50 percent. Used for general purpose springs with higher stresses, such as phonograph springs and spiral power springs. Comparative tensile strength is 250,000 lb. per sq. in.

(c) Carbon 0.90–1.05 percent; manganese 0.30–0.40 percent. Generally used for clock springs. Comparative tensile strength is about 275,000 lb. per sq. in.

(d) Carbon 1.10–1.20 percent; manganese 0.15–0.25 percent. Used for watch springs, main springs, and other highly stressed small, thin springs. Tensile strength may be as high as 325,000 lb. per sq.in.

Substitutions: for (a) use S.A.E. 1080; for (b) use S.A.E. 1085 and for (c) substitute S.A.E. 1095. For (d) order special steel to same composition as Swedish steel; these special compositions are available in limited quantities from manufacturers specializing in clock springs.

DESIGN CONSIDERATIONS

For many springs the simple substitution of an American steel for Swedish steel may be sufficient. For accurate springs and highly stressed springs, the lower ultimate tensile strength of the American substitute must be taken into account by redesigning the spring or the spring is not so highly stressed nor deflected so far. In many cases, the amount of redesign may be limited, as when replacing Swedish steel springs already in service.

Careful inspection and testing, both of the wire and of the finished spring, may reduce the number of early failures in springs made from American steels, but probably cannot eliminate them entirely. The defects in American steel wire may result from drawing the wire through the die too fast, causing the steel to neck down and stretch immediately upon leaving the die. This stretches the wire beyond the elastic limit and results in a wire of smaller diameter than the die.

Sometimes this wire may be drawn down to a smaller diameter in another die and passed off as good spring wire. However, it often contains seams. Such wire cannot easily be detected by tensile strength tests, so spring manufacturers resort to a torsion test wherein the wire is twisted until it breaks. As shown in Fig. 2, seams or otherwise defective wire usually appear before the break occurs in the twist test.

One of the many problems of substitutions for Swedish steel is in small springs with small wire diameter. Springs with indexes (ratio of spring diameter to wire diameter) equal to less than 3 and springs that are highly stressed or which must have an extremely long fatigue life, also present replacement problems.

PISTON RING EXPANDERS

Piston ring manufacturers, forced to use high-carbon American steel in place of Swedish steel, report domestic steel falls short of requirements in only one property—fatigue strength. Expander springs consist of a narrow ribbon of spring waved in such a manner as to exert spring action outward against the piston ring, forcing the ring against the cylinder wall.

Fatigue test used by one manufacturer consists of vibrating a sample 15,000,000 times at a frequency of 3,600 per min., duplicating engine conditions as nearly as possible. Swedish steel samples pass this test and are expected to withstand up to 40,000,000 vibrations. Steel that passes 10,000,000 vibrations will be satisfactory.

Analysis of steel is:

Carbon	1.00 percent
Manganese	0.25 percent
Chromium	0.20 percent
Silicon, Phosphorus, Sulphur	Traces

Tensile strength is 276,000 lb./sq. in.
Hardness is 50 Rockwell *C*.

Break test involves free bends over pins of specified diameters, depending upon size of sample undergoing test. Surface decarburization test is also applied.

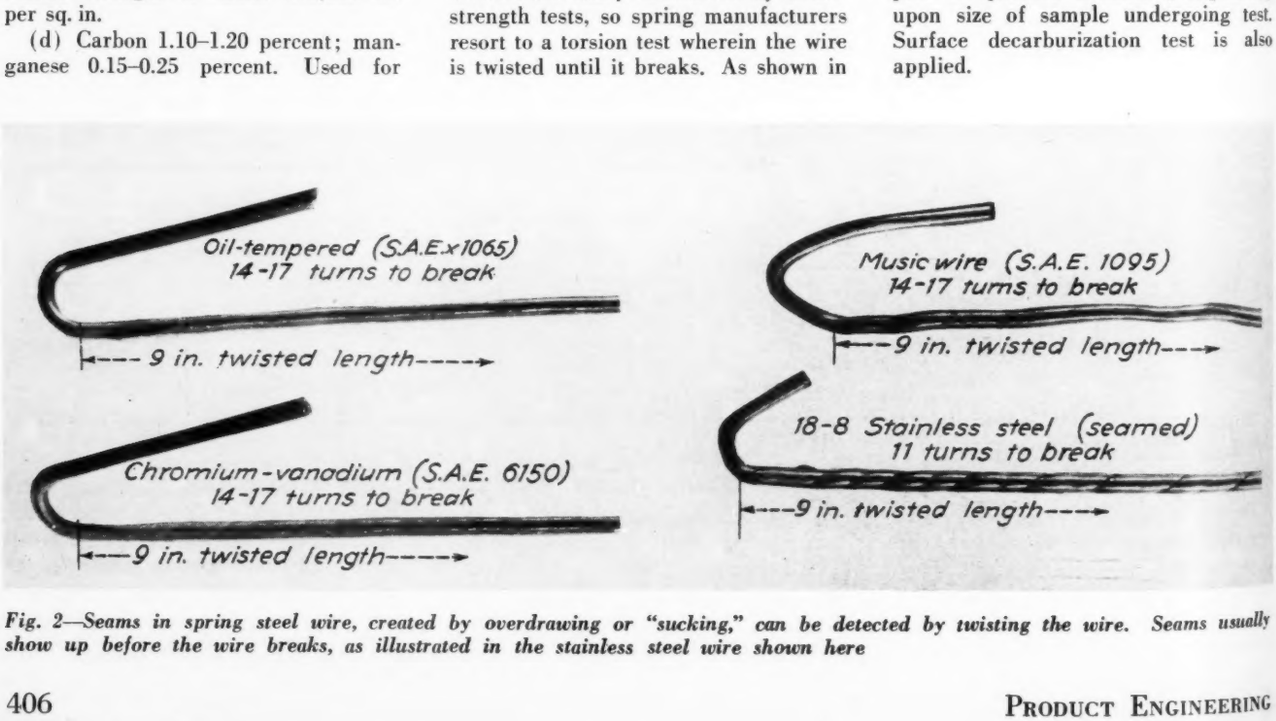

Fig. 2—Seams in spring steel wire, created by overdrawing or "sucking," can be detected by twisting the wire. Seams usually show up before the wire breaks, as illustrated in the stainless steel wire shown here

LEADED BRASSES

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Revere Copper and Brass Incorporated

IMPROVEMENT OF MACHINABILITY accounts for the addition of lead to brass. However, the influence of lead on other operations and serviceability of fabricated parts must be considered. Lead does not appreciably influence mechanical strength or corrosion resistance of brass but it does reduce the ease of flaring, upsetting, cold heading and bending.

In machining leaded brass the chips break off and do not overheat the cutting tool. Chips of copper-zinc alloys, however, are long and tough, making tool wear high and lubrication difficult.

SHEARING, BLANKING, and PIERCING operations are definitely improved by lead in brasses.

WHEN TO AVOID LEAD. Brass that is to be cold headed should contain little if any lead. Careful control of lead is required in brass that is to be brazed, welded or silver soldered. Where spinning, heavy knurling or heavy roll threading operations are to be performed, a high lead content should be avoided.

HOT WORKING. Hot working methods are unsuitable for fabricating alpha brasses containing lead because it renders them hot short. Alpha-beta brasses containing 55 to 60 percent copper can be hot rolled if the lead does not exceed one percent and can be hot forged with up to two percent lead. With more lead, cracking may occur in forging. As copper content increases beyond 60 percent, smaller amounts of lead can be tolerated until, between 63 and 64 percent copper, lead must be kept to a trace if hot working properties are required.

ANNEALING. In annealing leaded brasses care must be taken to avoid sudden exposure of cold worked parts or material to high temperature because lead makes brass more sensitive to "fire cracking."

FREE CUTTING BRASS ROD

The most important of all of the leaded brasses is free cutting brass, which contains 61.50 percent copper, 3.00 percent lead and 35.50 zinc. It is used in the manufacture of screws, nuts, bolts, door hinges and general hardware of all kinds. It is usually fabricated by hot extruding and cold drawing to size. It has excellent plasticity between 1,200 and 1,450 deg. F. and can be extruded without difficulty into intricate shapes.

Free-cutting brass rod is furnished commercially in the hard condition for best machining properties. If light upsetting operations are necessary in the manufacture of a part, it is best to use an annealed or soft rod, thereby sacrificing somewhat machining or free-cutting properties in order to obtain the ductility required. It cannot be hot rolled or forged. Physical properties are given in Figs. 1 to 6.

LOW LEADED ROD

Low leaded rod, which contains 0.50 percent lead, 63.0 percent copper, and 36.50 percent zinc, is used extensively in the manufacture of screws, bolts and similar parts that require good upsetting properties combined with fair machinability. While this alloy is more difficult to machine than free-cutting brass, the presence of 0.50 percent lead increases the machinability over that of a non-leaded brass in this composition range at not too great sacrifice of ductility.

An addition of 0.60 percent lead to an alloy of this type reduces the power required in machining 46 percent, while a 3.5 percent lead addition will only reduce it by 15 percent more. Figs. 7 to 12 show the influence of cold working and annealing treatment.

OTHER LEADED BRASSES

A wide range of compositions in leaded brass are available. The accompanying table shows how free-cutting and low leaded brass rods compare with other leaded brasses.

Hardware bronze has excellent cutting properties and its color approximates that of more expensive tin bronze. Its corrosion and tarnish resistance approximates that of copper.

Lancashire brass, widely used for clock parts, is most commonly made in strip form. It shears and punches with clean, smooth edges.

Leaded Hi brass is used extensively in strip form for deep drawing, stamping or any cold operation requiring unusual ductility. It also has good machinability, shearing and punching properties in combination with reasonably good bending and forming properties.

Light leaded brass rod has similar properties and is used for machined parts to be knurled.

Heavy leaded brass and engravers brass have good free-cutting properties but poor bending or forming properties.

Deep drilling rod gives minimum drill and tool wear.

Riveting and turning rod is a compromise between good machining and forming properties. It has good free-cutting properties and can be lightly cold worked by such operations as riveting, flanging, upsetting, knurling and roll threading.

Forging rod is used almost exclusively for hot pressing and hammer forgings. This alloy is extremely plastic between 1,200 and 1,450 deg. F. and is shaped hot into hardware, ammunition parts, valve stems, and plumbing fixtures.

Architectural bronze and extruded shape brass are considerably more plastic than forging rod.

(*continued on next page*)

Commercial Lead Brasses

Most Common Name	Most Common Analyses*	
	Copper Percent	Lead Percent
Hardware "Bronze"	87–90	1–2
Lancashire brass	73	2.50
Leaded Hi brass	65	0.90
Brass rod (leaded)	64	1.25
Heavy leaded sheet	64	2.50
Engravers brass	63.50	1.50
Leaded brass	62	1.50
Riveting & turning rod	62	1.60
Free cutting brass rod	61.50	3.00
Low leaded rod	63	0.50
Deep drilling rod	61.50	3.75
Forging rod	60	2.00
Extruded shapes	59	2.00
Architectural "Bronze"*	56.50	2.20
Red brass	55	1.50

* Remaining percent is zinc except that architectural bronze contains also 0.3 percent aluminum for its effect on color.

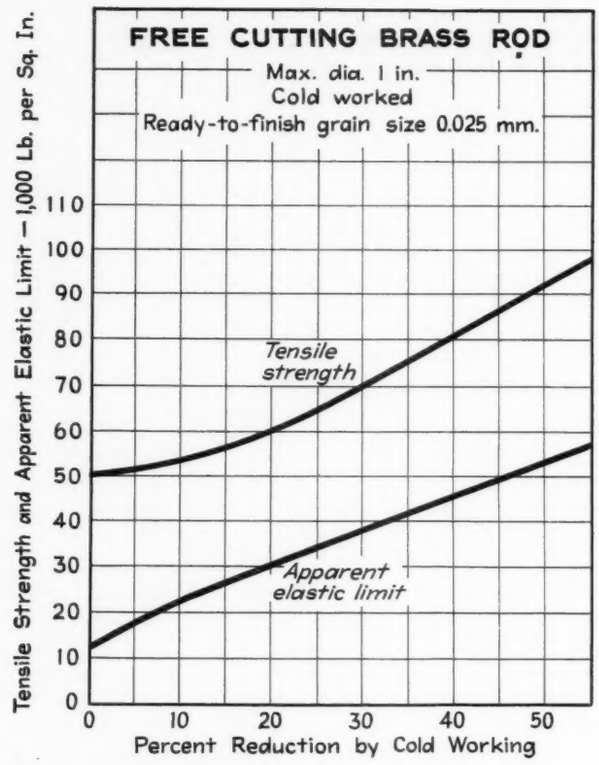

FREE CUTTING BRASS ROD
Max. dia. 1 in.
Cold worked
Ready-to-finish grain size 0.025 mm.
Tensile strength
Apparent elastic limit
Tensile Strength and Apparent Elastic Limit — 1,000 Lb. per Sq. In.
Percent Reduction by Cold Working

Fig. 1—Effect of cold work on tensile strength and apparent elastic limit of free cutting brass rod (60.99% copper, 3.13% lead) previously extruded to a grain size of 0.030 mm.

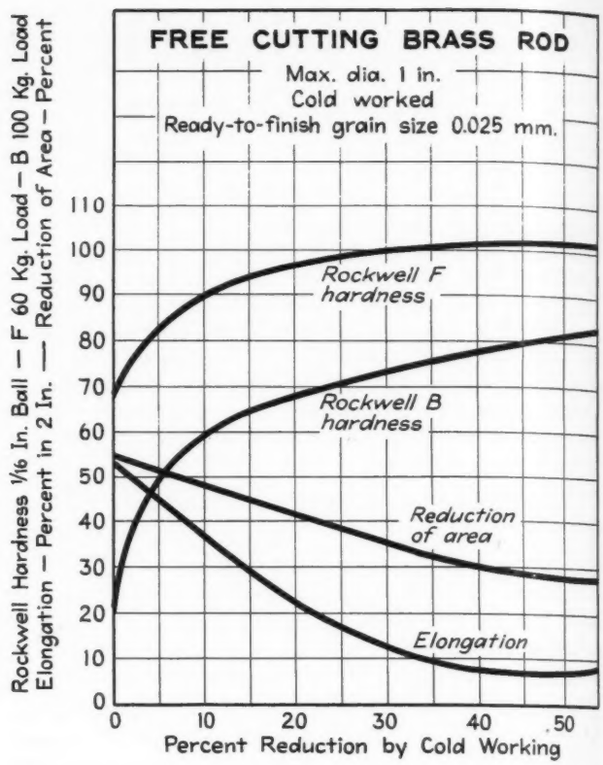

FREE CUTTING BRASS ROD
Max. dia. 1 in.
Cold worked
Ready-to-finish grain size 0.025 mm.
Rockwell F hardness
Rockwell B hardness
Reduction of area
Elongation
Rockwell Hardness 1/16 In. Ball — F 60 Kg. Load — B 100 Kg. Load
Elongation — Percent in 2 In. — Reduction of Area — Percent
Percent Reduction by Cold Working

Fig. 2—Effect of cold work on Rockwell hardness, percent elongation and percent reduction of area of free cutting brass rod previously extruded to a grain size of 0.030 mm.

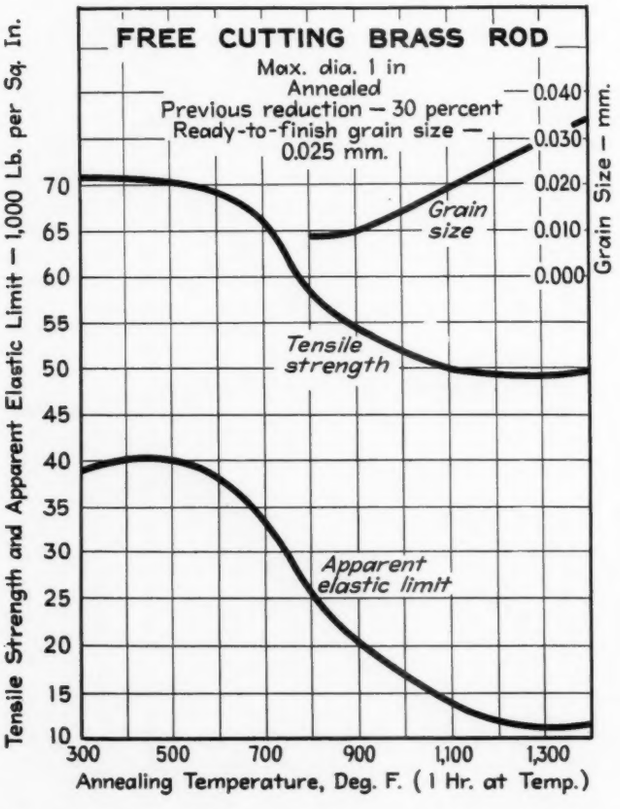

FREE CUTTING BRASS ROD
Max. dia. 1 in
Annealed
Previous reduction — 30 percent
Ready-to-finish grain size — 0.025 mm.
Grain size
Tensile strength
Apparent elastic limit
Tensile Strength and Apparent Elastic Limit — 1,000 Lb. per Sq. In.
Grain Size — mm.
Annealing Temperature, Deg. F. (1 Hr. at Temp.)

Fig. 3—Effect of annealing on tensile strength, apparent elastic limit and grain size of free cutting brass rod previously cold drawn to 30 percent reduction of area from extruded material having a grain size of 0.030 mm.

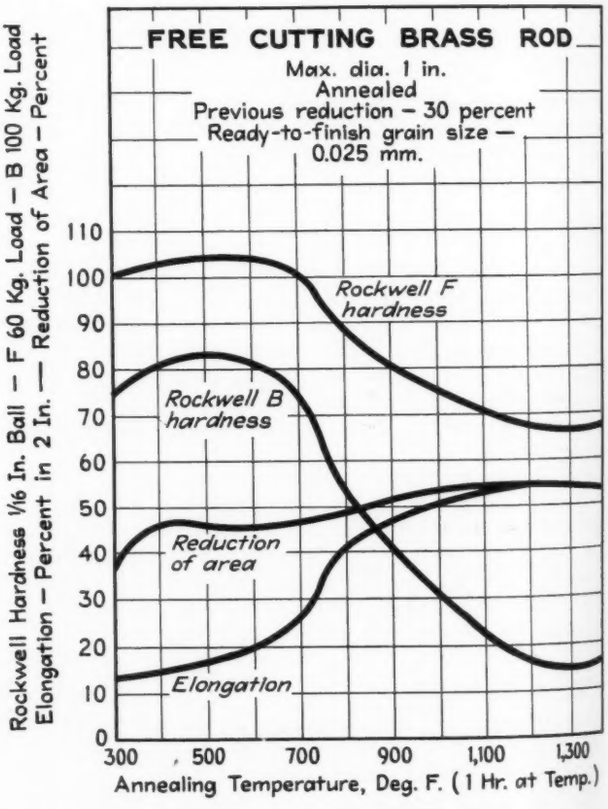

FREE CUTTING BRASS ROD
Max. dia. 1 in.
Annealed
Previous reduction — 30 percent
Ready-to-finish grain size — 0.025 mm.
Rockwell F hardness
Rockwell B hardness
Reduction of area
Elongation
Rockwell Hardness 1/16 In. Ball — F 60 Kg. Load — B 100 Kg. Load
Elongation — Percent in 2 In. — Reduction of Area — Percent
Annealing Temperature, Deg. F. (1 Hr. at Temp.)

Fig. 4—Effect of annealing on hardness, elongation and reduction of area of free cutting brass rod previously cold drawn to 30 percent reduction of area from extruded material having a grain size of 0.030.

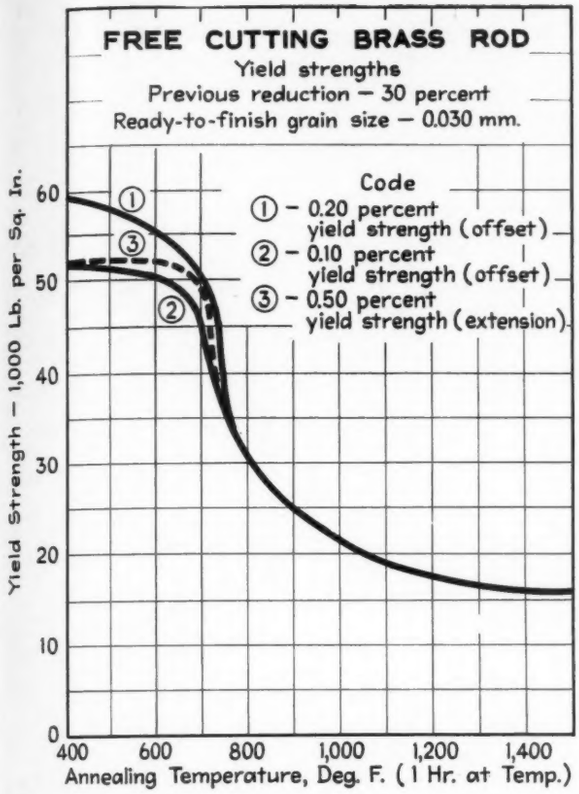

FREE CUTTING BRASS ROD
Yield strengths
Previous reduction — 30 percent
Ready-to-finish grain size — 0.030 mm.
Code
① — 0.20 percent yield strength (offset)
② — 0.10 percent yield strength (offset)
③ — 0.50 percent yield strength (extension)
Yield Strength — 1,000 Lb. per Sq. In.
Annealing Temperature, Deg. F. (1 Hr. at Temp.)

Fig. 5—Effect of annealing on yield strength of free cutting brass rod previously cold drawn to 30 percent reduction of area from extruded material having a grain size of 0.030 mm.

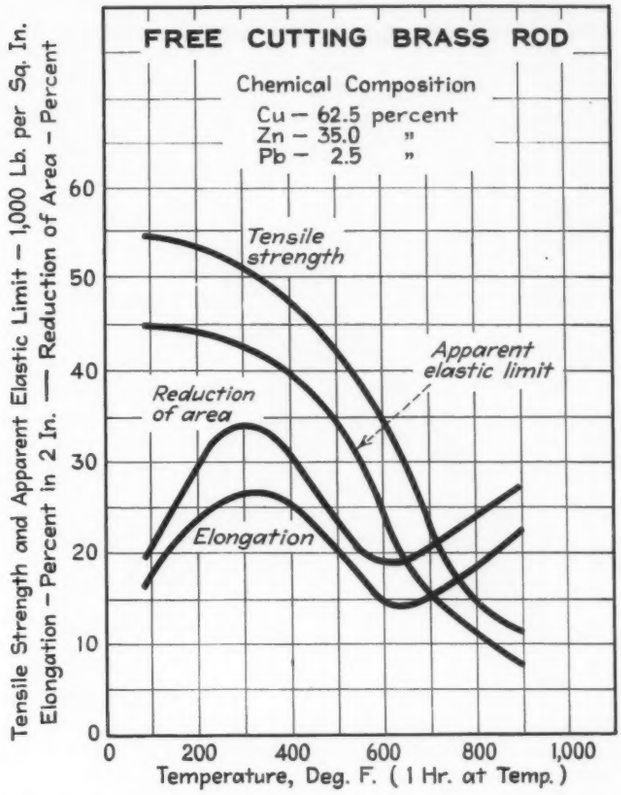

FREE CUTTING BRASS ROD
Chemical Composition
Cu — 62.5 percent
Zn — 35.0 "
Pb — 2.5 "
Tensile strength
Apparent elastic limit
Reduction of area
Elongation
Tensile Strength and Apparent Elastic Limit — 1,000 Lb. per Sq. In.
Elongation — Percent in 2 In. — Reduction of Area — Percent
Temperature, Deg. F. (1 Hr. at Temp.)

Fig. 6—Effect of elevated temperature on tensile strength, elastic limit, reduction of area and elongation of free cutting brass rod as reported by The Crane Company.

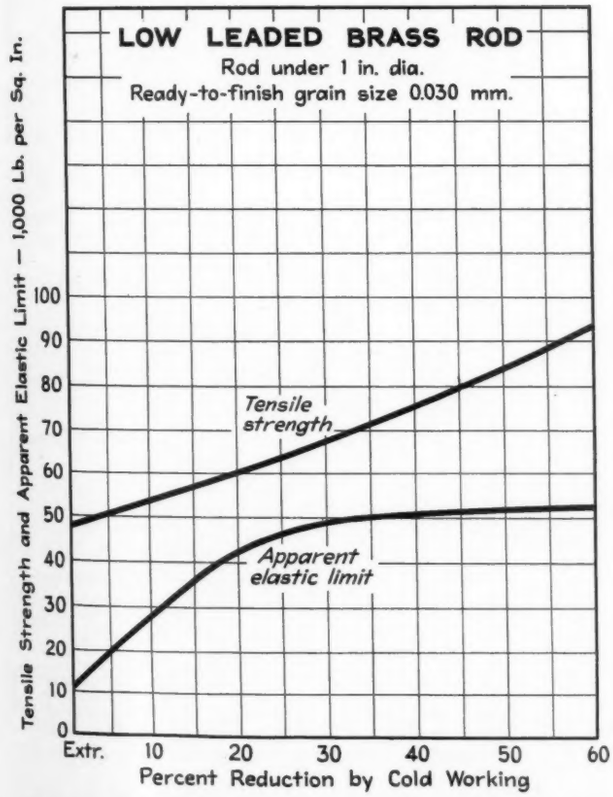

LOW LEADED BRASS ROD
Rod under 1 in. dia.
Ready-to-finish grain size 0.030 mm.
Tensile strength
Apparent elastic limit
Tensile Strength and Apparent Elastic Limit — 1,000 Lb. per Sq. In.
Percent Reduction by Cold Working

Fig. 7—Effect of cold work on tensile strength and apparent elastic limit of low leaded brass rod (62.95% copper, 0.69% lead) previously extruded to a grain size of 0.030 mm.

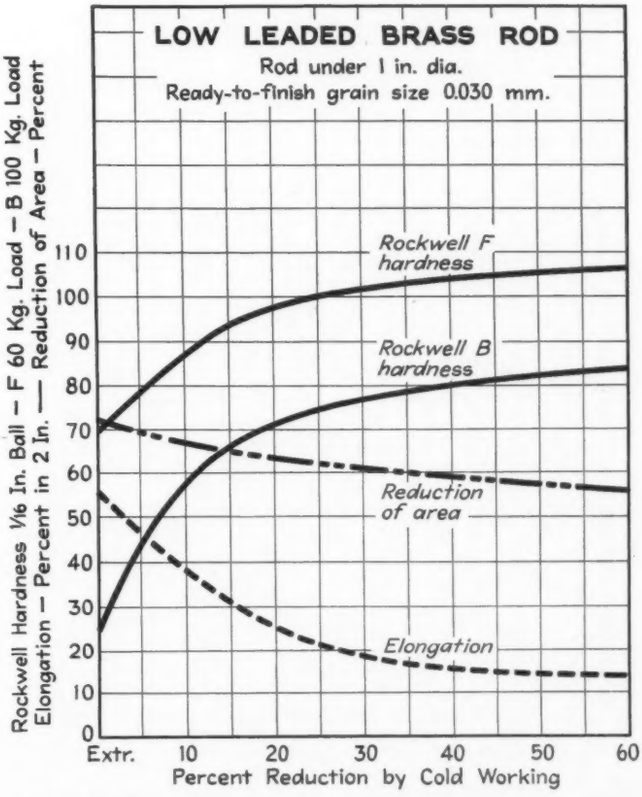

LOW LEADED BRASS ROD
Rod under 1 in. dia.
Ready-to-finish grain size 0.030 mm.
Rockwell F hardness
Rockwell B hardness
Reduction of area
Elongation
Rockwell Hardness 1/16 In. Ball — F 60 Kg. Load — B 100 Kg. Load
Elongation — Percent in 2 In. — Reduction of Area — Percent
Percent Reduction by Cold Working

Fig. 8—Effect of cold work on Rockwell hardness, percent elongation and percent reduction of area of low leaded brass rod previously extruded to a grain size of 0.030 mm.

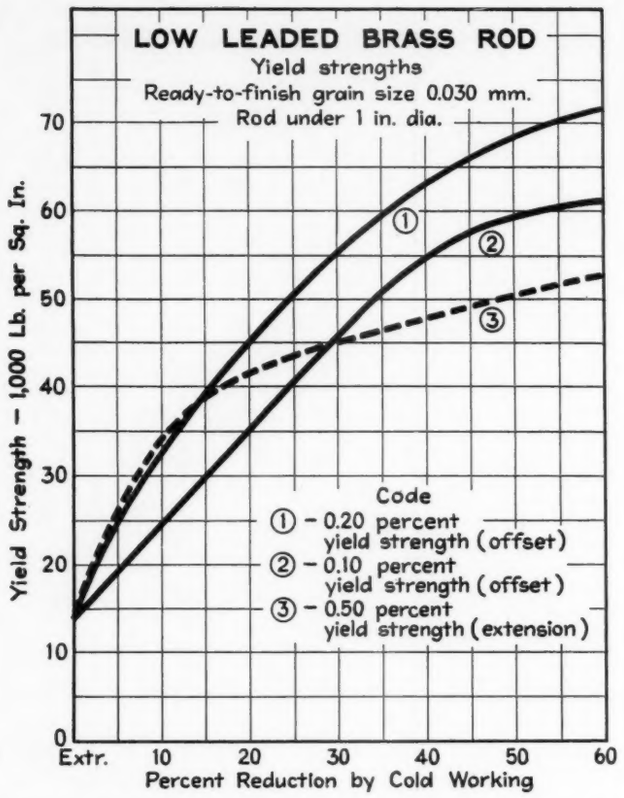

LOW LEADED BRASS ROD
Yield strengths
Ready-to-finish grain size 0.030 mm.
Rod under 1 in. dia.
Yield Strength – 1,000 Lb. per Sq. In.
Code
① – 0.20 percent yield strength (offset)
② – 0.10 percent yield strength (offset)
③ – 0.50 percent yield strength (extension)
Extr.
Percent Reduction by Cold Working

Fig. 9—Effect of cold work on yield strength of low leaded brass rod previously extruded to a grain size of 0.030 mm.

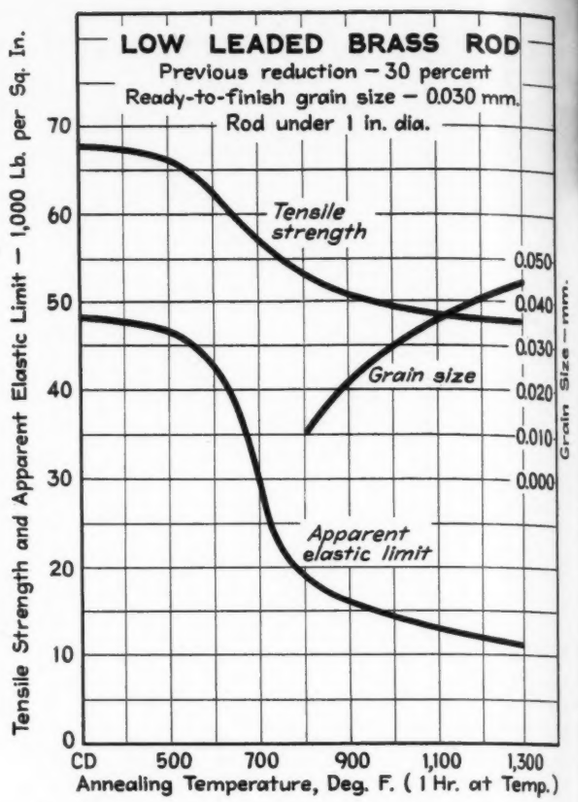

LOW LEADED BRASS ROD
Previous reduction – 30 percent
Ready-to-finish grain size – 0.030 mm.
Rod under 1 in. dia.
Tensile strength
Grain size
Apparent elastic limit
Tensile Strength and Apparent Elastic Limit – 1,000 Lb. per Sq. In.
Grain Size – mm.
Annealing Temperature, Deg. F. (1 Hr. at Temp.)

Fig. 10—Effect of annealing on physical properties of rod previously cold drawn to 30 percent reduction of area from extruded material having a grain size of 0.030 mm.

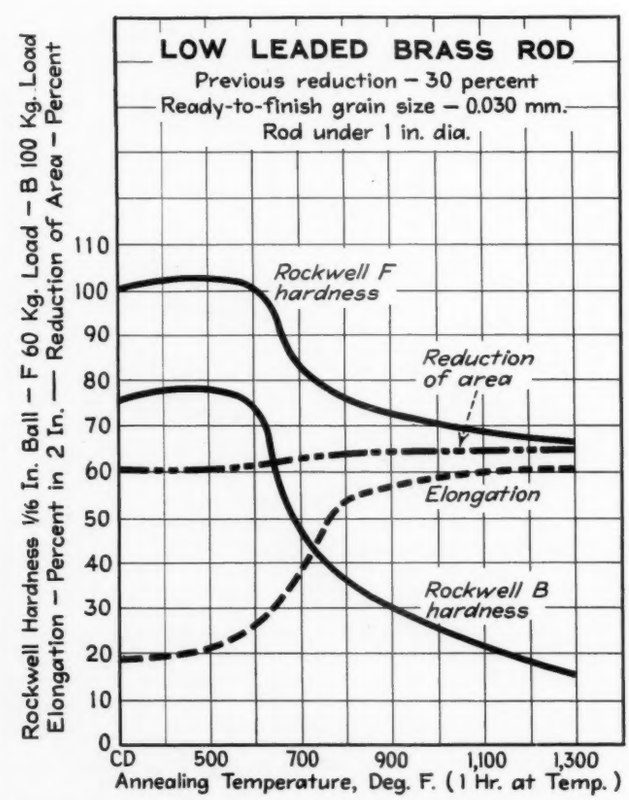

LOW LEADED BRASS ROD
Previous reduction – 30 percent
Ready-to-finish grain size – 0.030 mm.
Rod under 1 in. dia.
Rockwell F hardness
Reduction of area
Elongation
Rockwell B hardness
Rockwell Hardness 1/16 In. Ball – F 60 Kg. Load – B 100 Kg. Load
Elongation – Percent in 2 In. — Reduction of Area – Percent
Annealing Temperature, Deg. F. (1 Hr. at Temp.)

Fig. 11—Effect of annealing on hardness, elongation and reduction of area of low leaded brass rod previously cold drawn to 30 percent reduction of area from extruded material having a grain size of 0.030 mm.

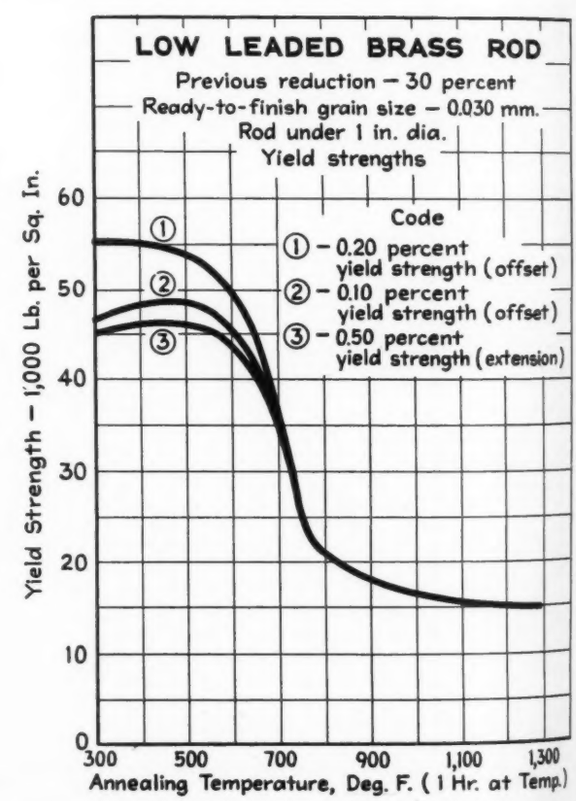

LOW LEADED BRASS ROD
Previous reduction – 30 percent
Ready-to-finish grain size – 0.030 mm.
Rod under 1 in. dia.
Yield strengths
Code
① – 0.20 percent yield strength (offset)
② – 0.10 percent yield strength (offset)
③ – 0.50 percent yield strength (extension)
Yield Strength – 1,000 Lb. per Sq. In.
Annealing Temperature, Deg. F. (1 Hr. at Temp.)

Fig. 12—Effect of annealing on yield strength of low leaded brass rod previously cold drawn to 30 percent reduction of area from extruded material having a grain size of 0.030 mm.

Question and Comment

Design of Gear Pumps

JOHN C. MONAHAN
Hydraulic Engineer, Gar Wood Industries, Inc.

IN CONNECTION with hydraulic control units described in the "Modern Designs" section of the June issue of PRODUCT ENGINEERING (p. 313), the following basic facts concerning the design of the conventional gear pump have been collected by and for engineers of this company.

The type of pump under discussion has an output capacity of 5 to 100 gal. per min. at speeds up to 1,500 r.p.m. and pressures up to 1,000 lb. per sq. in. In general, its essential construction consists of two identical, involute tooth spur gears mounted on shafts which run in plain, ball or roller bearings, with the whole bounded by a gear housing and two wear plates.

In designing a pump, it is often necessary to predict the volumetric output, within reasonably close limits, at a certain predetermined speed and pressure. A commonly used method for calculating this for gear pumps is as follows:

(1) Find the working depth of tooth (Addendum × 2).

(2) Subtract the working depth of tooth from the outside diameter to obtain the working root diameter.

(3) Subtract the area of the working root diameter from the area of the outside diameter to find the differential area.

(4) Assume that the total displaced tooth-area is one-half the differential area. Multiply one-half the differential area by the gear length to find the volume pumped by each gear in one revolution.

This method is wrong. It is assumed that the area of the tooth-pocket is equal to the area of the tooth. Actually this condition exists only in a rack. It can be seen that, with a given pitch and number of teeth, the tooth-pocket-area becomes proportionately larger as the pitch diameter is decreased.

To determine accurately the volumetric output, it is necessary to consider the volume of oil displaced in each tooth pocket. The volume displaced is represented by the shaded area. This is a greater area than has generally been considered. In explanation, visualize the tooth entering the shaded area of the tooth pocket. Displacement takes place immediately and fluid is prevented from passing to the input side by the contact of the previous tooth mesh. Eventually the tooth makes its own contact, which continues down the tooth pocket flank, to the point of contact at dead-center position, and then up the other side. At dead-center the tip of the tooth displaces its own area and thus the whole shaded area is accounted for.

It may be noted here that a relief port is usually provided in the wear plates to carry to the output side any oil which might otherwise be trapped. This relief should extend between the gears, from the center line to a point outside the path of the gear teeth. It should be as wide as the working depth and deep enough to prevent restriction.

To find the volume of fluid pumped in one evolution, the displaced area in the tooth-pocket must first be calculated, then multiplied by the length of the gear and by the sum of the number of teeth in the gears.

Method for Calculating Output

The area-layout method is exact, but quite long and complicated since it involves the calculation of an area bounded by circular arcs and involute curves. An easier method, which is accurate within an average of 1.3 percent by actual test on a number of pumps, is presented here. First, find the torque at unit pressure as follows:

(1) Find working depth of tooth (Addendum x 2).

(2) Assume that the center of mass of the displaced area is ⅓ of the working depth, measured from the outside diameter.

(3) Mean radius of hydraulic force = pitch radius $+ \frac{\text{working depth}}{6}$.

(4) Torque = mean radius × working depth × length of gear.

Assuming an overall efficiency of 100 percent and using a speed of 1,000 r.p.m. for convenience, proceed as follows:

(5) hp. input $= \frac{\text{torque} \times \text{r.p.m.}}{63{,}000}$

(6) hp. input = hp. output.

(7) g.p.m. output $= \frac{\text{hp. output}}{0.000583}$

or, g.p.m. output $= \left(\text{pitch } R. + \frac{\text{Add.}}{3}\right) \times$ add. × length × 3,430.5.

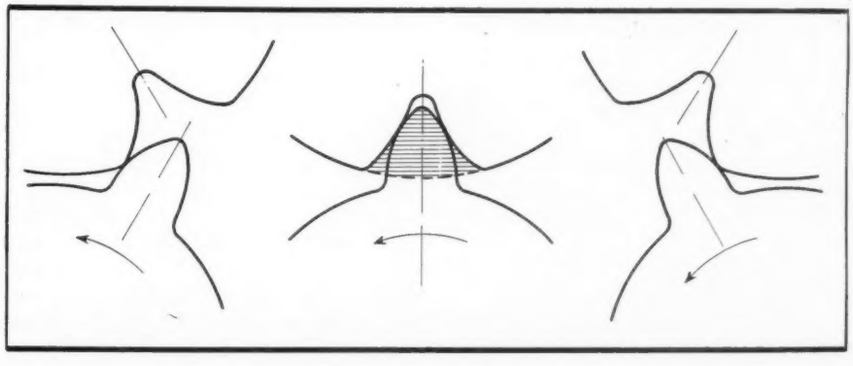
The same procedure can be followed to find the torque output of a fluid motor. In each case the efficiency at various pressures and speeds must be considered in the design.

Suggestions for Design

1. It is apparent that a gear tooth with a high-pressure angle and a narrow tip will provide the greatest tooth space area. However, the gears may be noisy if the pressure angle is too high. It is best to keep the pressure angle below 30 deg. and to use a long addendum tooth with the least possible amount of undercutting.

2. Most of the volumetric loss in a gear pump is caused by leakage of oil past the ends of the gears. The gear housing length should be held as close as possible to the length of the gears, provided that just enough clearance is maintained to prevent freezing.

3. A deep tooth is always more efficient volumetrically than a shallow tooth on the same pitch diameter. This



is due to the fact that leakage is dependent on oil pressure and clearance only, and does not change with the capacity of the pump. Thus, in a deep tooth design the leakage is of lesser proportion to output than in a shallow tooth design.

4. For the same reason, a long gear is more efficient than a short gear. However, the length is necessarily limited by the load-carrying capacity of the bearings.

5. It has been found that no bearing is rigid enough to prevent deflection of the pump shafts under high oil pressure. This deflection must be allowed for to prevent serious gouging of the housing bore by the pump gears. For pumps developing 1,000 lb. per sq. in., the housing bore should be at least 0.010 in. larger than the outside diameter of the gear.

6. Backlash has little effect on the volumetric efficiency if proper relief is provided for trapped oil. Gears should have the amount of backlash needed to minimize noise of operation.

It is sometimes desirable to use inserted type wear plates to reduce cost. These plates, having a contour conforming to the shape of the gear housing bore, are placed in each end of the gear housing. However, this is not good practice for high-pressure pumps for the following reasons: (a) The coefficient of expansion of the wear plate material is usually higher than that of the gears and the housing. This means that additional end clearance must be maintained to prevent freezing at high temperatures (b) There is always a certain amount of leakage around the contour of the wear plates.

8. It has been found that ball bearings have a longer life than roller bearings, of equal rated capacity, if any abrasive elements are present in the fluid being pumped. (Assuming that the bearings are exposed to this fluid).

9. The pump speed should never exceed 1,500 ft. per min. pitch line velocity.

10. The best pump shaft oil seal is the garter type with finger spring and heat resisting material. Never use this type on shafts exceeding 750 ft. per min. peripheral speed.

11. Intake opening should be as large as possible. Both intake and output openings should be cored in the form of a trumpet.

12. Use a good, hard-drying gasket cement in preference to gaskets if the sealing surfaces are sufficiently smooth and flat.

13. Never use gaskets between two highly finished surfaces.

14. Provide enough pump bolts to resist stretching and resultant leakage.

15. Bronze wear plates of 80–10–10 composition have proved to be the best. (80 percent copper—10 percent tin—10 percent lead).

Belated By-line

Due to an oversight, Mr. R. H. Rogers of the Industrial Engineering Department of General Electric Company was not given proper credit as the author of the article "Power Linkages and Their Applications," in June PRODUCT ENGINEERING.

Wrench Clearances

Supplementing the article "Wrench Clearances," by Arthur H. Korn, in the March issue of PRODUCT ENGINEERING, this data on cast iron pipe flanges may be added to Table II, page 156.

Flanged Pipe Clearances

Required for open end 45 deg. offset wrench
Dimensions X, Y and R in in., α in deg.

Nominal Pipe Size	Cast Iron Flanges 25 lb. per sq.in.			
	X	Y	R	α
4	5.0	12.7	14.5	98
5	5.7	12.9	15.0	96
6	6.5	13.3	15.6	93
8	7.2	14.1	16.7	95
10	10.7	15.8	18.1	83
12	11.9	16.7	19.4	83
14	13.4	19.3	22.4	83
16	16.1	21.0	23.6	75
18	16.9	21.6	24.4	75
20	18.2	22.9	25.5	70
24	20.5	24.9	27.8	71

Gas Leakage

To the Editor:

In answer to F. D. Howe's inquiry for data on leakage through small fissures (June P. E. "Questions and Comment" dept.), I should like to call your attention to a paper on this subject presented by Adolf Egli at the meeting of the A.S.M.E. held in New York in November, 1936. Later presented in the "Journal of Applied Mechanics" of June, 1937, Vol. 4, No. 2, it is titled, "The Leakage of Gases Through Narrow Channels."

Theory developed as basis for calculations is given practical demonstration through tests on leakage of air and steam through the slight clearance between a valve stem and bushing. A solution is given in graphical form to show the relation between mass flow, pressure drop and channel resistance.

—J. OSKER
Elizabeth, N.J.

Flameproof Diesel Engine

Mine explosions due to ignition of gasses long have baffled engineers. The Bureau of mines now has completed a chamber in which it can place a diesel mine locomotive and control the atmosphere which mixes with its fuel (which affects the composition and heat of its exhaust) at the same time testing the possibility of ignition of the atmosphere by the exhaust. Main feature of the "flameproof" diesel, developed by Dr. R. R. Sayers, is water-cooling and filtering of the exhaust.

Can You Work This One?

H. E. SMITH

Solution to June problem—

Beggars' Game

Let x equal the number of pennies each had at first. Number Three received x, took out $(2 + 4)$, and put in $\frac{X}{2}$; the sack then contained

$$\left(\frac{3}{2}x - 6\right)$$

For simplicity, let a equal $\frac{3}{2}$. Then Number Five received $(x.a - 6,)$ took out $(4 + 1)$, and put in enough to multiply the contents of the sack as he received it by a. The sack now contained $(xa^2 - 6a - 5)$. Number Two took out $(1 + 3)$ and handed on $(xa^3 - 6a^2 - 5a - 4)$. Number Four took out $(3 + 5)$ and handed an $(xa^4 - 6a^3 - 5a^2 - 4a - 8)$. Number One put in 2. The sack now contained $5x$.

Hence

$$xa^4 - 6a^3 - 5a^2 - 4a - 6 = 5x$$

$$x = \frac{6a^3 + 5a^2 + 4a + 6}{a^4 - 5}$$

Substituting $\frac{3}{2}$ for a,

$$x = 696$$

This month's problem—

An Apple a Day

A servant was charged to deliver to His Royal Highness, the King, an apple a day for a week from a highly prized tree which was guarded by three men. To get the apples, the servant was to give each guard one half of what he carried plus one half of an apple, without cutting, slicing or breaking the fruit. How many apples did he pick to fulfill his mission?

Case Histories In Patent Law

H. A. TOULMIN, Jr.

(EDITOR'S NOTE: *The purpose of these Case Histories is to give a better understanding of the patent law in the public interest. The author advises that actual cases should be submitted to your own patent attorney.*)

No. 29

Question: What is a Patent Office Interference?

Answer: The Patent Office has set up machinery for determining who is the first inventor when applications on the same invention are filed in the Patent Office and pending there at the same time. Despite all efforts for its simplification, Patent Office interference contests are very intricate in their procedure. Indeed, the conduct of them is almost a specialty in itself.

When the Patent Office finds that the claims in one application read upon the invention in another's application, or the claims in an issued patent can be made to read upon a pending application disclosure, it declares what it calls an "Interference", which is just another name for a procedure to determine who is the first inventor.

Each inventor is called upon to file a statement of his dates of invention under seal without disclosing his invention to the other. Usually neither party knows when the other's application was filed.

If either party wishes to show any reasons why he thinks the other party has no right to claim the invention or has a different invention, or the invention is old and cannot be claimed, he must state them before he can see the preliminary statement of the other.

If all these questions are decided adversely to the party raising them, then the Patent Office sets time during which testimony is taken by the respective contestants from their witnesses to prove their records of invention.

After this testimony is taken and filed in the Patent Office, the preliminary statements having been opened for inspection of the respective parties prior to its taking, the Patent Office hears the contestants and decides which one is the first inventor.

The rules are extremely complicated in determining this matter. For instance:

In Laas et al. v. Scott et al., 161 Fed. Rep. 122 (E.D. Wis. 1908), the court discussed the question of diligence as follows:

". . . . Under our patent system, he who first arrives at a complete conception of the inventive thought is entitled to recognition and reward, unless and until the interest of the public is compromised by his lack of diligence in demonstrating that his invention is capable of useful operation. . . . . Therefore, the inventor who first reduces the discovery to practical operation is held to be prima facie the true inventor, without regard to the date of his conception. But the earlier inventor may overcome this presumption and prevail if he can show by satisfactory evidence continuous diligence to perfect and utilize the invention. Thus with nicety and fairness has the law adjusted the respective rights of rival inventors consistently with the general welfare." (p. 126)

In Seeberger v. Dodge, 24 App. D. C. 476, it was held that where an inventor cannot reasonably reduce to practice, he should show diligence by applying for a patent. The Court said:

" 'Granting the contention that actual reduction to practice is preferable to that which is constructive merely, as more to the interest of the public, and that reasonable indulgence ought to be extended to one pursuing that course in good faith, yet, when the construction of an experimental device involves so great cost and risk that an inventor, though possessed of sufficient means, may well hesitate to undertake the same entirely at his own expense, due diligence requires that he should then attempt to secure his right and promote the public interest by filing an application for a patent.' "

In McParland v. Beall, 45 App. D. C. 162, the Court said:

"In the present case, the Commissioner of Patents held that 'where both parties reduce at the same time he who first conceived the invention must be regarded as the first inventor'. This must be so since only the party last to reduce to practice can be penalized for lack of diligence. Neither party having reduced to practice prior to the filing of his application, and therefore, being neither a junior nor a senior party, but each standing on the same footing as to reduction to practice, it cannot be said that the one first to conceive is junior for the mere purpose of establishing lack of dilegence. It follows that, where both reduce to practice on the same day, the one first to conceive must be held to be the inventor and entitled to priority."

In Eastman v. Houston, 18 App. D. C. 135, the party Houston endeavored to corroborate his disclosure through seven witnesses, offering evidence a dated sketch and a camera made according to his invention in 1893, and these were held to be insufficient. In the course of its opinion the court stated:

" . . . . But no one testifies to the fact of identity of the contents of the box, except Houston himself, and his testimony cannot be accepted as sufficient to establish the fact. Disclosure, in the sense of the patent law, must be made ordinarily to persons competent to understand and appreciate the alleged invention. Otherwise, there is no true disclosure. We are unable to find in the record any sufficient or satisfactory disclosure of the invention by the appellee at any time before he came into the Patent Office with his application for a patent. The only proof that he had the invention at any time before the date of that application, or before the day on which the application was sworn to, is his own unaided testimony; and this, of course, cannot be accepted without corroboration."

But in the case of General Talking Pictures v. American Tri-Ergon Corp. (C.C.A. 3), 96 F. (2d) 800, the corroboration offered by DeForest, one of two interfering applicants, was held to be sufficient. DeForest conceived his invention while on the high seas, October 12, 1918, on a British boat. He immediately disclosed his invention to a Mr. Darby, his patent attorney, a fellow passenger, by means of a short description and sketch made on a piece of stationery of the "Carmania", the boat upon which they were passengers. In the interference DeForest corroborated his testimony by Mr. Darby and by the sketch and written description.

On the question of diligence in reducing to practice, DeForest introduced the testimony of several witnesses who assisted him in experimental work on his invention on DeForest's return to America. As to this the Court stated:

" . . . . The uncontradicted testimony of these witnesses serves to show quite apart from any testimony on the part of DeForest himself, that he was actually experimenting with lights in the nature of glow lights, with platinum electrodes, and with slit apertures within a comparatively short time after the date of his alleged conception of the invention, the date of the "Carmania" memorandum of October 12, 1918. Such evidence seems to us plainly to support the conclusion reached by the tribunals of the Patent Office, giving credence to the "Carmania" memorandum." (P. 810)

News and Summaries

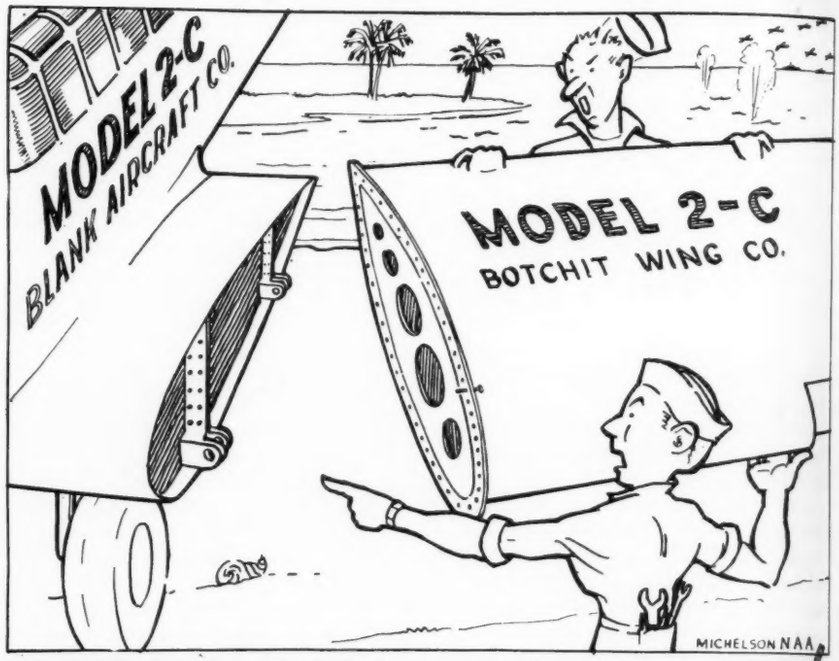
Solution Prevents Corrosion of Containers

WHEN ADDED in small amounts to clear lacquers, alcoholic shellacs and nitrocellulose solutions such as pyroxylin and collodion, a material known as D.P. Solution, developed by Merrimac Division of Monsanto Chemical Company, prevents corrosion of steel in contact with the solution. Thus, tin lined shipping drums are not needed. About 100,000 pounds of tin will be saved since two pounds of tin have been necessary to coat the interior of a 55 gallon drum of the type used in the shipment of industrial lacquers.

Tin lined drums were required because of the tendency of the lacquers to corrode iron or steel, a condition which not only spoiled drums but also discolored lacquer.

The solution has undergone practical testing in lacquers shipped in unlined drums from Boston through the Panama Canal to the Pacific coast. Despite rapid changes in weather and long exposure to high temperature, the drums were reported to have arrived without corrosion.

About one half ounce of D.P. Solution to a gallon of lacquer is sufficient. Protective action is set up by reaction of the solution with the metal surface of the drum to produce an insoluble film. Microscopically thin, the film mends itself in case of a break.



Posters such as this are now being exchanged between member companies of the National Aircraft Standards Committee of the Chamber of Commerce to encourage standardization of aircraft design.

Properties of Synthetic Resin Treated Woods

PLASTICS INSTITUTE Research Project X-164, reported by F. J. Grush, determined the resistance offered by various woods, untreated and impregnated with synthetic resin, to penetration of a steel ball pressed against the flat surface.

Woods used were pieces Oregon Pine, 2x2x2, and Balsa wood. 1x1x1½ in. Treating material was phenolic resin impregnating varnish.

Specimens of both woods were immersed in water soluble phenolic resin for periods ranging from 1 to 24 hours. They were air dried for 48 hours and cured for 1 hour at 150 deg. C.

A steel ball of ½ in. diameter was pressed into the center of test samples, both parallel and perpendicular to grain, by a universal testing machine at a speed of 0.05 in. per min. An automatic recording chart plotted penetration into wood as a function of load applied. From results of the test, tabulated below, it was concluded that impregnation with synthetic resin increases the hardness of wood surfaces.

Treatment conditions	Wood	Maximum Load in Lb.	
		Parallel to grain	Perpendicular to grain
No treatment	Pine	235	1050
1 hr. in phenolic resin	Pine	683	1260
No treatment	Balsa	45	85
1 hr. in phenolic resin	Balsa	50	130
24 hr. in phenolic resin	Balsa	55	183

Brazed Joints Stronger Than Metals Joined

A REPORT of the American Silver Producers' Research Project states that joints brazed with silver alloys are readily made stronger than the metals so joined. Although it is not always true of butt joints, it can be made true of lap and scarfed joints if the length of lap or scarf is made adequate. The report claims that even butt joints produced by brazing stainless steel with silver alloy have been found to have a tensile strength as high as 134,000 lb. per sq. in.

Although the design of the joint is probably the most important factor

controlling its strength, there are other, controllable conditions including the kinds of metals joined, clearances between parts, and, in some cases, the operator's skill. Research of this group has shown that, under most conditions, a joint has maximum strength when clearances into which silver alloy is flowed are approximately 0.0015 in. However, tests using stainless steel and silver brazing alloy in any properly made joint under 0.0005 in. clearance show a tensile strength of at least 100,000 lb. per sq. in.

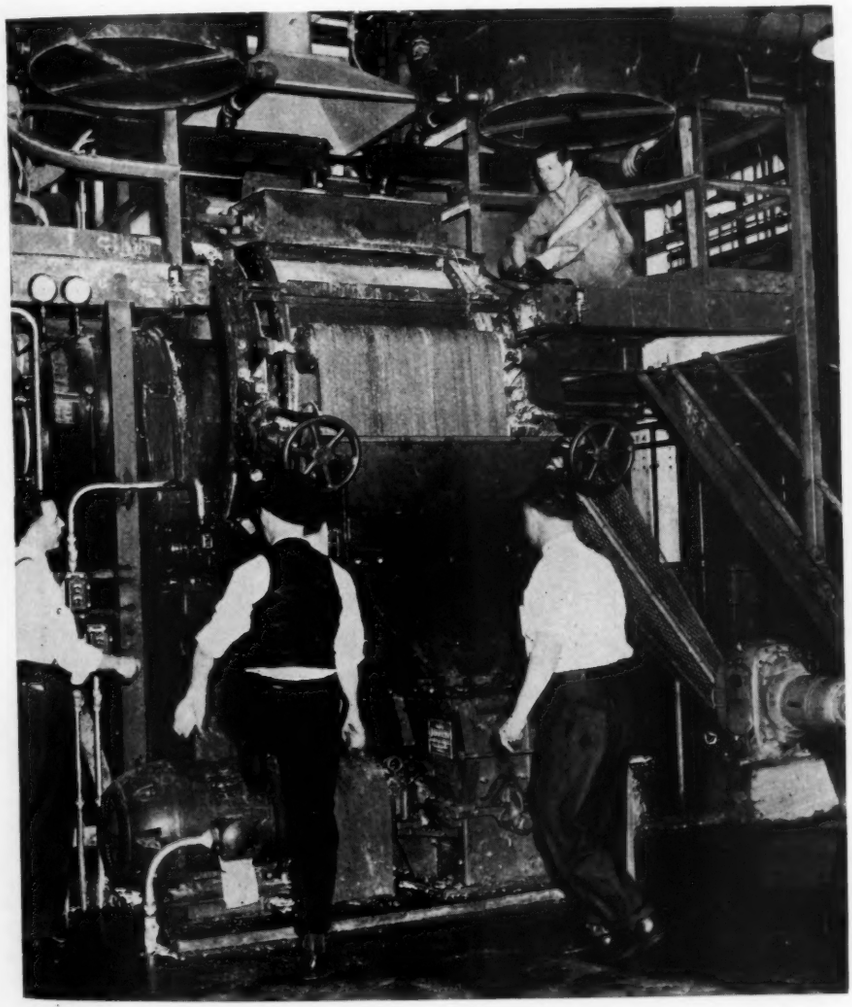
Since silver alloys penetrate into small fissures, joints made with smallest clearances are generally strongest, and it is wasteful to provide wide clearances or fillets as is often done with soft solders. Thus little brazing alloy per joint is required.

Bullets X-rayed in Action

ARMY BALLISTICS TECHNICIANS now have twin X-ray units by which to study the action of bullets within gun barrels and as they pierce steel armor plate. Built by Westinghouse, units are capable of delivering charges of 2,000 amperes at 300,000 volts in a millionth of a second. They stand side by side so that separate exposures made on film during the flight of a bullet will measure elapsed time of bullet travel between the two points.

Elapsed time can be measured from 1/500 sec. to 1/1,000,000 sec. Two exposures can also be made simultaneously. More machines, now being built, will increase the number available for test purposes. Four are expected to be in use at the Frankford Arsenal and two at the Aberdeen proving grounds.

Manufacturers state that the most powerful of the usual industrial X-ray machines now in operations would require exposures 10,000 times longer than the new units to penetrate an inch of steel. The increased power of this high-speed X-ray lies in its ability to withstand high amperage.



Chemigum synthetic rubber production in the Goodyear Tire and Rubber Company's plant is expected to be in full operation with an annual capacity of 15,000 tons within a short time. Workmen here are watching the first batch roll out in a new government sponsored plant. Additional facilities for another 15,000 tons are expected to be completed by November this year. Most of this synthetic will be devoted to tires for the Army and Navy. Some for oil resistant engine fittings, gaskets and couplings.

Plastic Spacers Saves Critical Metals

TO CONSERVE BRASS AND STEEL, plastic spacers have been reported as substitutes for metal spacers on milling machine arbors. Called "Artus Spacers," they are made by Industrial Products Suppliers of New York City from Plastacele, cellulose acetate plastic produced by Du Pont.

Plastic spacers are produced in ten thicknesses, each with identifying color, from 0.001 to 0.020 in., with hole diameters as high as 2 in. with standard keyways. Larger sizes up to 10 in. can be obtained. It is claimed they retain thickness and evenness under all normal working conditions.

Reclaiming Oil

AS PART of their salvage operations, Wright Aeronautical Corporation have set up stills to reclaim and restore to usefulness thousands of gallons of used cutting oil and oil from engine tests.

Substitutes in Light Bulbs

TWO MILLION POUNDS of brass a year will be saved by the substitution of iron bases and other conservation measures in the manufacture of electric light bulbs, according to a report from the Westinghouse Lamp Division. Products affected will be all civilian bulbs in sizes from 10 to 300 watts and most industrial lamps. Nickel will be conserved through the substitution of nickel-plated iron wire for pure nickel wire. A reduction of 50 percent in tin used has been made possible by lowering the ratio of tin in the base solder tip and by reducing the size of the tip itself.

Do You Know That—

MANGANESE BRONZE is virtually exclusively specified for propellers on ships built for the Navy and the Maritime Commission. (11)

PRICKLY PEARS are the basis for a new explosive called Yabardita, said to be only 3 percent less powerful than TNT. (12)

ENGINEERING IN WASHINGTON

McGRAW-HILL WASHINGTON BUREAU, *PAUL WOOTON, CHIEF*

Cargo aviation takes the spotlight in Washington engineering. Donald Nelson has appointed a cargo airplane committee to investigate the possibilities of air cargo on an unprecedented scale in this war. Reasons for the investigation are mainly two: (1) transport planes—for troops, civilians, and freight—have achieved results here in the United States, on the trans-Africa line, and on the China-Burma battle fronts, far beyond expectations; (2) ocean shipping has fallen far behind in the transportation of our war production for our allies, and the conviction that airplanes could substantially alleviate the situation is growing strong in many quarters.

Nelson's problem is whether to recommend that all our available capacity be put to work on turning out the heavy transport designs which we already have in the air—like Lockheed, Douglas, Boeing, Sikorsky, Curtiss-Wright—or concentrate on development of the 150-ton and bigger planes now only on paper. The big planes on blueprint could not be put in the air in volume in less than three or four years. We could put large numbers of existing types aloft in a year or two. It's a matter of "calculated risk," as the generals say. In other words, are we to have a long or short war?

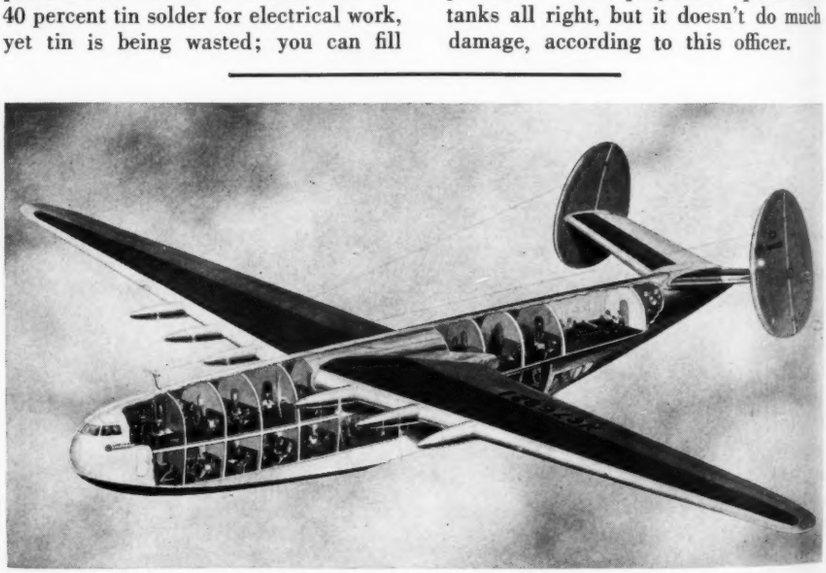
The blueprint planes are not merely something somebody hopes will fly. Foremost among them is Glenn Martin's 250,000-pound "air vessel," powered by six engines, to carry a 50,000-pound load. At least one other first-line company has a still bigger plane in mock-up form. It is safe to say that all the builders of big airplanes have much larger ones on their drawing boards. Thus, the Administration would not be gambling current proved designs against unproved paper designs. Glenn Martin has stated recently that his staff is convinced there is no structual or aerodynamic limit to any size of plane we might want for practical purposes.

Current transport planes are carrying heavy "pay" loads to most of our war fronts—going the long way around, it's true, for the advantage of short hops, but getting there. It sounds like fourth grade arithmetic, but some transportation experts are concluding that the equivalent of the cost of a ship, invested in aiplanes will deliver more goods from point A to point B in a year than the ship will because the plane will make scores of trips to two or three by the ship. And the air cargo will be out of reach of submarines all the time, and beyond any form of attack part of the time; there is yet no weapon against airplanes in darkness or daytime overcast.

Highlights on materials, from a speech by George Brady, Chief, Materials Statistics, Office of Imports, Board of Economic Warfare, before convention of purchasing agents: "Before we are through with the present effort I say we will be using aluminum and magnesium as substitutes for other metals, even in ships . . . A great accomplishment was the steel mills' changeover from dip tin plate to electrolytic tin plate, which requires only one-third the amount of tin to give a good coating . . . Our list contains more than 4000 different raw materials . . . Do not expect too much of synthetic rubber; it is better than natural rubber for some uses but will not replace it . . . There is no substitute for 40 percent tin solder for electrical work, yet tin is being wasted; you can fill practically every bearing need with little or no tin . . . Oil fractionation will be one of the big advances of the war; we will not buy oils by names of plants and animals, but will call for synthetics by characteristics . . . Copper is a rare metal; after the war we should turn our designs towards nature's plentiful aluminum and magnesium . . .

Nickel must be conserved, says the War Production Board, in letters to a large group of machinery manufacturers, including machine tool builders. Tool builders object, saying that changes to other alloys will seriously consume engineering, executive and shop time. The Board replies that the nickel must be saved, and it asks everybody to do his best. Engineers on the Board say that too many designers get alloy habits and resist disturbing changes.

A German anti-tank gun discharges its projectile at the unprecedented speed of 4000 feet per second, according to a British tank officer. This speed is achieved by making the gun 12mm. smaller at the muzzle than it is at the breach, which sets up great compression. The projectile penetrates tanks all right, but it doesn't do much damage, according to this officer.

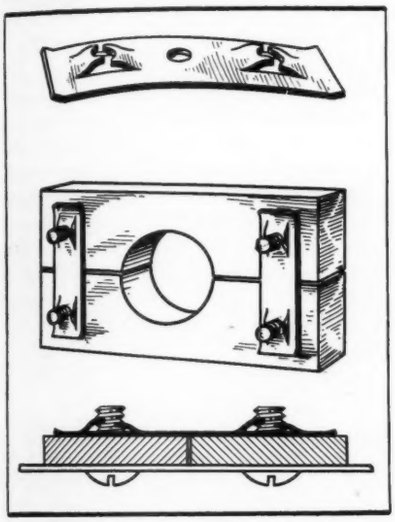


Glenn L. Martin's design for a 250,000-pound flying ship which will carry 102 passengers, each with 80 pounds of luggage, plus 25,000 pounds of mail and cargo to London in 13 hours. As a military transport, the ship could carry large numbers of troops and heavy supplies. This company's present flying boat, the 140,000-pound Mars, now ready for tests, could carry 150 armed men and their equipment, if she were used as a transport. The interior of her hull is equivalent to the interior of a 15-room house.

New Materials and Parts

Twin-Type Speed Nut

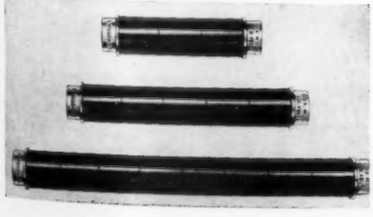
To reduce both weight and assembly time for attachment of fairlead guide blocks in aircraft construction. Only a screw driver is needed for assembly. Twin Speed Nut can be used for other attachments throughout the plane where



fastening points are grouped in pairs. Manufactured with or without center hole for riveting as desired. Made in sizes with distance from center to center of screw holes ½, ⅝, ¾, ⅞ and 1 in.—for either AN 515–6 and –8 or Air Corps 530–6 and –8 screws. Tinnerman Products, Inc., 2041 Fulton Rd., Cleveland, Ohio.

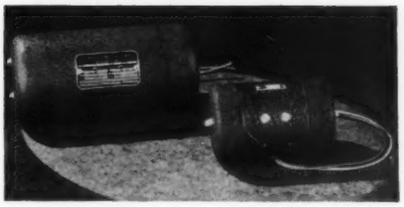
Sectional Resistor

Sectional Resistor made up of individual, hermetically sealed units wire wound around a ceramic resistor spool. Units have values of from 0.25 to 1 megohm and a rated current of 1 milliampere. Dimensions are 1⅜ by 1¼ in. in diameter per section. Ceramic spools are sectionalized and adjacent sections wound in opposite directions for non-inductive resistance. Voltages, a.c. or d.c., from 250 to 30,000 may be measured. Resistor intended for use in railway service, radio circuits, power rectifiers and laboratories. Tolerances are said to be close enough to allow interchangeability of units having same voltage ratings. Multiplicity of resistance combinations in one complete unit are permitted by taking off a permanent tap between any two sections. Westinghouse Meter Division, Newark, N. J.



Dynamotors

Five types of dynamotors for communication and other service in aircraft, tanks and mobile field equipment. Outputs range from 25 to 600 watts and weights from 3 to 31 lb. Features claimed include light weight and reliability under rigorous conditions. Alternating current ripple is kept at a value requiring minimum of filter to provide satisfactory operation of communication equipment. Other features are Formex wire, spiralled armature punching to reduce noise and eliminate locking effect, and stator formed from stainless steel tubing. In the illustration is shown d-c dynamotors for aircraft—left, 100 watts, 28 to 575 volts, and right, 15 watts, 25 to 250 volts. General Electric Co., Schenectady, N. Y.

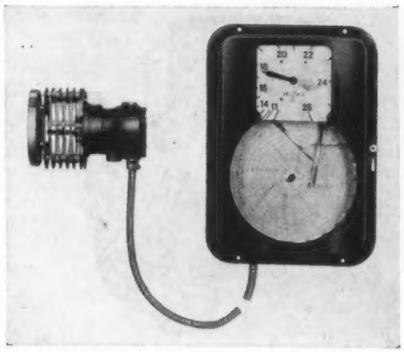


Pencil Tracing Cloth

Tracing cloth with processed surface to take penciled lines. Cloth said to be tough, durable and not to discolor with age. The back is glossy and transparent to increase speed in print production. Manufacturers claim that a 5H or harder pencil will produce lines of same density as a 2H or 3H on ordinary tracing cloth. Details may be erased with soft eraser without showing on blueprint. Supplied in 20-yd. rolls, in widths of 30, 36 or 42 in. or in sheet sizes to suit. The Frederick Post Co., Box 803, Chicago, Ill.

Radiation Pyrometer

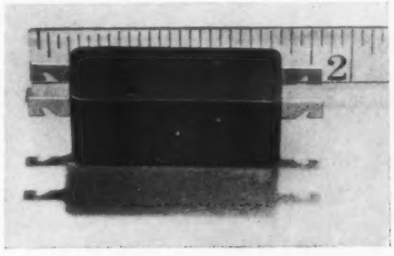
Known as the "Pyrovac," instrument records, indicates and automatically controls temperatures in furnaces and kilns above 900 deg. F. Temperature sensitive unit or radiation head is mounted on outside of furnace, out of



the hot zone, where it picks up heat rays emitting from the object under measurement, thus registering surface temperature of the work. Among advantages claimed is measurement of temperatures out of ordinary thermocouple range temperatures for which rare-metal thermocouples are used. Also that it records temperatures of the work itself rather than furnace or kiln temperatures surrounding the work. It is useful where object is moving, or inaccessible, or where there are space limitations. The Bristol Co., Waterbury, Conn.

Miniature Switch

Designed for use where space is limited and vibration conditions severe. Called "Switchette," the unit weighs 9 grams and is intended to meet Air Corps requirements for devices of this type. Switch can be operated by lever, bellows or other actuating means by movement of a spring-return button in the housing. Contacts arranged for



single-pole normally open, single-pole normally closed, or single-pole double-throw operation. Each form available with contact air gap of 0.010, 0.020, or 0.030 in. Overall dimensions are 1¾ x $\frac{18}{32}$ x ½ in. General Electric Co., Schenectady, N. Y.

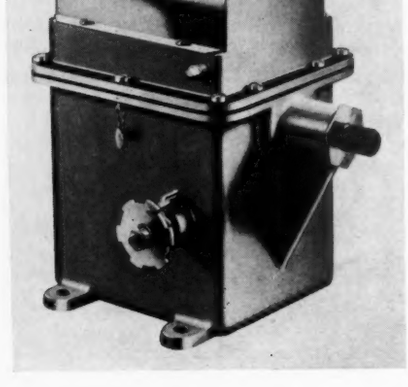
Switch Actuator

Specifically intended for use in throttle mechanisms of aircraft but with potentialities of wider application. Listed as type "T," actuator provides positive means of circuit closure and a manual release feature that automatically resets the switch for the next cycle of operation. The actuator accepts the

manufacturer's type R-31 switch; is supplied as a single unit or in assemblies of 2, 3 or 4 units, left or right hand, spaced to meet customer's specification. Micro Switch Corp., Freeport, Ill.

Electric Valve Control

High torque proportioning control motor, "Microtrol," with built-in limit switches and potential dividing rheostats for operating butterfly valves, multiple radial fuel valves and regulation of dampers in air conditioning and drying systems. Output shaft driven by a shaded pole induction motor through gear reduction. Oil-submerged units are sealed in die-cast case. Barber-Colman Co., Rockford, Ill.



Covers for Bearings

Standard covers in a wide range of types and sizes for forming dust and grease-tight closures to housings of ball and roller bearings. Chief advantages are said to be low unit cost, savings in set up, reduction in designing, drafting, detailing and checking time and the elimination of the cost of patterns, fixtures, gages. R-S Products Corp., 4530 Germantown Ave., Philadelphia, Pa.

Moisture Resistant Switch

Metal-clad, sensitive, snap-action switch designed to meet Army Air Corps specification 94-32249, with special over-travel plunger mechanism mounted in zinc or aluminum die-cast housing. Neoprene bellows seals operating plungers against most oils, moisture, dust, soaps, etc. Switch operates through a temperature range of from −10 deg. F. to +150 deg. F. Elec-

trical ratings are 25 amp. at 28 volts d.c., 17 amp. at 125 volts a.c., 8.5 amp. at 250 volts a.c., 3 amp. at 460 volts a.c. and 2 amp. at 600 volts a.c. Switch is rated at ½ hp. at voltages of 115 to 460 a.c. Special mounted lugs can be supplied to allow use of ring type wire connectors. Wiring connections supplied normally open, normally closed, or single-pole double throw. Operating pressure supplied range from 6 to 28 oz. Pre-travel and over-travel can be adjusted, although normal pre-travel is approximately 0.010 in. and over-travel 0.125 in. Mu-Switch Corp., Canton, Mass.

Lacquers for Black Plate

A series of lacquers for coating black plate (substituted for tin or Terne plate) prevent under-film corrosion. Lacquers are said to withstand processing for home canning. They can be made in metallic colors. The Albert P. Hill Co., Inc., Pittsburgh, Pa.

Sensitive D-C Relay

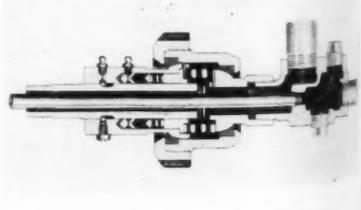
For aircraft service, relay CR 2791-C100-C is designed for use in vacuum tube output circuits where small power available requires operation on low current. Relay protected against dust and damage by sealed aluminum cover, weighs 3¼ oz. and is intended to meet Air Corps requirements for devices of this type. Maximum continuous current rating is 2 amp. at 32 volts, and maximum make or break rating is 10 amp. Contacts provide single pole, double throw operation. General Electric Co., Schenectady, N. Y.

Substitute for Tin Base Babbitt

Two lead base bearing metals known as Pyramid and Defender. Pyramid, suited to applications where bearings must withstand heavy sustained pressures, is suggested for such equipment as marine reciprocating engines, paper mill calendar stacks and rolling mill machinery. Defender, for use where bearing metal must withstand shock without cracking, is intended for such applications as internal combustion engines, trap rock crushers and sifter machinery. Magnolia Metal Co., 120 Bayway, Elizabeth, N. J.

Revolving Joint

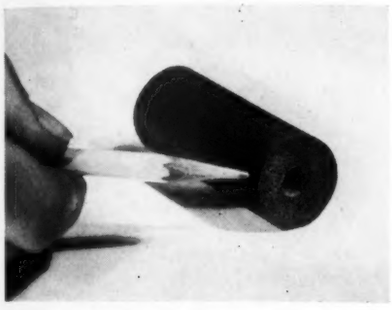
Capable of handling steam, air, oil, gas, water and other fluids. Two ball seats permit slight flexing angle to relieve strain on piping due to pulling together nipples and unions. Joint is



equipped with a ball race arranged so that the sleeve has a slight tendency to move in and out for expansion of the pre-heated and cooling rolls. The chevron packed seal is maintained by constant pressure of a spring against the packing. Repacking of the joint is possible without removing the threaded sleeve from the roll. Barco Mfg. Co., 1801 Winnanac Ave., Chicago, Ill.

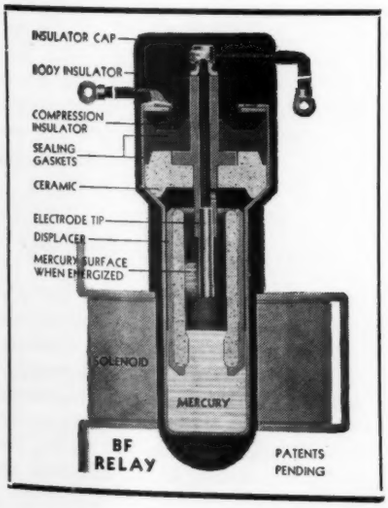
Reclaimed Rubber Sponges

Blown sponge rubber products made of 100 percent reclaimed rubber are said to have practically the same properties as sponge made from crude rubber, particularly in the compression ability of the material. Reclaimed sponge is manufactured in various molded or tubular shapes or in slabs which can be cut into shapes desired. The B. F. Goodrich Co., Akron, Ohio.



Mercury Relay

Working under a hydrogen quenching atmosphere, arcing, pitting or burning of the electrical contact members in this relay, are eliminated, There are no moving parts other than the liquid and its float. Manufacturers claim the relay will successfully undergo unusual knocks and hardships without damage. Durakool, Inc., 1010 N. Main St., Elkhart, Ind.

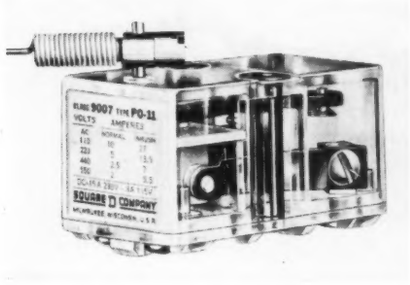


Etched Plastic Nameplates

Cellulose acetate dials, scales, instruction plates, nameplates, and similar items now available make possible the saving of critical metals normally used. The new plastic plates are etched by a recently developed process, and have high visibility, good corrosion resistance, and are easy to clean. The plastic material is not soluble in oils, and can satisfactorily be used in machine tools. Its light weight is of particular value in aircraft. Plates are available in a variety of color combinations and fluorescent materials. Eastern Etching & Mfg. Co., Chicopee, Mass.

Precision Limit Switches

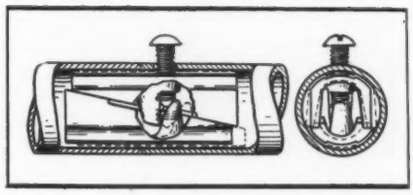
Class 9007—Type P switches designed for use where space and operating force are limited. Switch units measuring 2x1x1 in. are inclosed in transparent molded polystyrene cases, sealed against tampering. Operating lever can be adjusted to any position in a complete circle. Switch operates on



15 deg. travel and permits an additional 40 deg. over-travel in either direction. Toggle mechanism operates with 2½ oz. of force applied to a 1-in. lever arm. Die-cast closures for surface-mounting type measure 3⅞ in. by 1 1/16 in. by 2 5/32 in. A flush type arrangement is also available to permit the switch to be built into the machine casting. Either push rod or roller arm actuators used. Inclosed type requires 5 deg. rotation for operation and allows 25 deg. over-travel in either direction. Return spring readily shifted to reverse contact action or provide latch type operation. Industrial Controllers Division, Square D Co., 4041 N. Richard St., Milwaukee, Wis.

Expansion Coupling

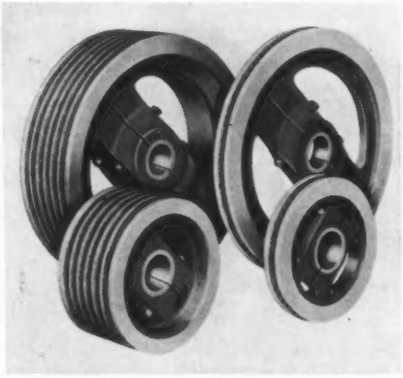
Advantages claimed for the Millock coupling are that only one hole is required in one wall of one pipe end; lining up is accurate; coupling applied to one pipe end with screw cannot come



apart; universal grip; no pipe deformation and ease of handling in installation. Mueller Specialty Mfg. Co., 6007 S. Carpenter St., Chicago, Ill.

Wood Sheaves for V-Belts

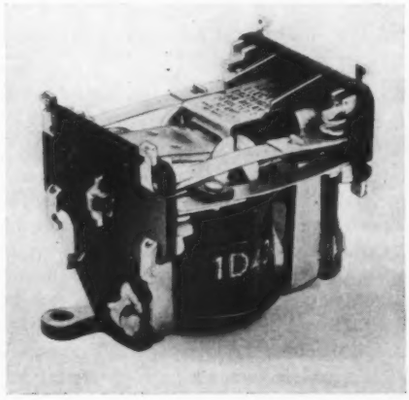
Laminated wood sheaves with segments of straight-grain, kiln-dried, hard maple designed as alternates for metal sheaves. Wood bushings provided can be fastened to shaft. Called "Victory" sheaves, they come in composite groove types for "A" and "B" section belts in a full range of sizes and for "B" belts



in sizes from 5.4 P.D. to 38.0 P.D. up to 10 grooves, and for "C" belts from 5.4 P.D. to 44.0 P.D. up to 12 grooves. Dodge Mfg. Corp., Mishawaka, Ind.

Aircraft Relay

A 4-pole relay designated CR 2791-GLOOK. Features claimed are light weight, permanence of contact position, assurance of operation under severe vibration conditions and operation at



high altitudes at rated current. Maximum continuous current rating is 10 amp. at 12 or 24 volts d.c. and maximum make or break current rating is 50 amp. at 12 or 24 volts d.c. Normally open contacts have tip travel of $\frac{3}{4}$ in. Relay measures $2\frac{1}{2}$ x $1\frac{5}{32}$ x $1\frac{25}{32}$ in. and weighs 0.281 lb. The General Electric Co., Schenectady, N. Y.

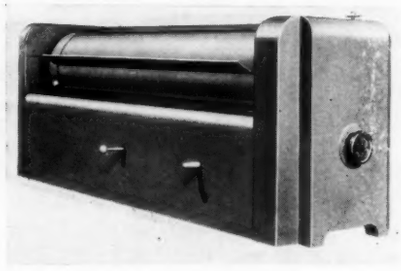
Low Frequency Generator

For use in conjunction with an oscillograph or with photographic recording apparatus, this low frequency linear-time-base generator is applicable for the investigation of low frequency transient and recurrent phenomena, such as vibration studies and low frequency electrical observations. Frequency range corresponds to rotating speeds of 12 to 7,500 r.p.m. Transient observation is provided for by a single-stroke sweep circuit. Known as the Type 215, the generator has a sweep

frequency range of 0.2 to 125 cycles per sec. Maximum undistorted output signals is approximately 450 volts, peak to peak, balanced to ground. Instrument measures 14 1/2 x 8 13/15 x 19 1/2 in., and weighs 41 lb. Operation is on 115 or 230 volts a.c., r.m.s., 40 to 60 cycle. Power consumption is 50 watts. Allen B. Dumont Laboratories, Inc., 2 Main Ave., Passaic, N. J.

Dark Room Printer

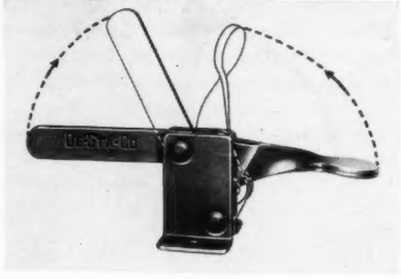
Small dark room printer provides positive contact, accurate light control, variable speed control, adequate speed for all dark room printing requirements, compactness and durability. The 9 in. deep contact glass, slightly curved to insure contact, is special Trans-peco glass which passes a high percentage of actinic light. The endless chain type contact band is of black, two-ply seamless fabric to prevent light leakage in the dark room. Two 40-watt white fluorescent tubes are the light source. Amount of printing light desired is controlled



by a shutter which, when closed, completely surrounds the tubes. This shutter is composed of two semi-circular stainless steel elements which swing from the same hinge. The printer is driven by a ¼-hp., 110-volt a.c. variable speed motor. A two-speed gear shift provides a speed range of from approximately 2 in. to 3 ft. per min. in low gear, and of from 10 in. to $5\frac{1}{2}$ ft. per min. in high gear. The combination of a variety of shutter opening adjustments and controlled variable speeds makes possible a great variety of exposures. Overall dimensions of the machine are 22x60x18 in. Table space required is 60x18 in. Net weight, approximately 240 lb. C. F. Pease Co., Chicago, Ill.

Toggle Type Clamp

Small horizontal-type toggle switch especially designed for aircraft applications. Known as the "De-sta-co" toggle clamp No. 205, it measures $1\frac{5}{16}$ in. high and $\frac{5}{8}$ in. from handle tip to arm tip, weighs $3\frac{1}{8}$ oz. Handle and arm are in horizontal position when clamp is locked. Detroit Stamping Co., Detroit, Mich.

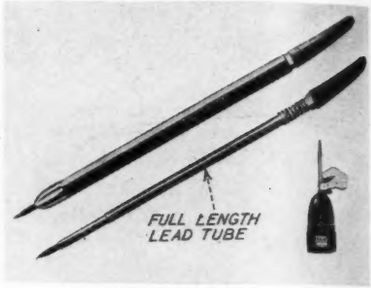


Metal Lead Primer

A lead primer is said to be equal in its protective value to that of a good grade of aluminum paint. Called "Hyspar," it may be brushed, sprayed, or dipped, and dries hard in four to five hours. Gray in color, this paint is said to hold tight to metal under rapid climatic changes, to be crack- or flake-proof, and highly resistant to salt-impregnated air of the seaboard. The Midland Paint & Varnish Co., Cleveland, Ohio.

Mechanical Drafting Pencil

This mechanical drafting pencil has a full-length lead tube of spring brass which is driven downward into the chuck point by a screw-operated mechanism to provide positive grip on lead and prevent slippage or wobble. The pencil barrel is made of light weight cellulose acetate. Pencil is also



made in a double-end type for carrying two different degrees of lead in one holder, or a lead in one end and a scriber in the other. A line of drawing leads for these pencils comes in nine degrees of hardness. A motor-driven lead pointer that starts and stops automatically is also available. Tec Pencil Co., 9381 Olympic Blvd., Beverly Hills, Calif.

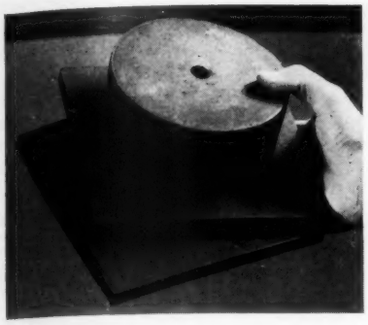
Insulation Varnish

For application to electrical apparatus intended for operation at 250 deg. C., or higher. Designated as S-110, this thermosetting varnish is said to dry at 175 to 200 deg. C., all the way through deepest windings. The dried film is said to be mechanically strong, adhesive, flexible, and to retain heat characteristics under extreme heat conditions. The Sterling Varnish Co., 167 Ohio River Blvd., Haysville, Pa.

Hard Cellular Rubber

Ameripol synthetic rubber now produced as a hard sponge possesses the same properties and general characteristics of regular Ameripol compound in resistance to action of oil, greases and other solvents. Light in weight, the material can be sawed or drilled, has good acoustic properties, and does not

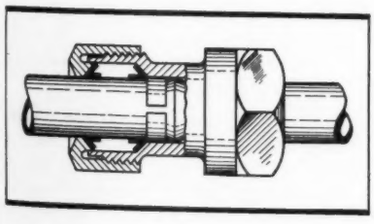
show any degree of injury after prolonged subjection to heat of 158 deg. F. Low water and oil absorption is said to make it particularly adaptable as a



float material. Produced in slab or molded form, manufacturer's test has shown that a mechanical pressure of 225 lb. per sq.in. will not injure its cellular makeup. The B. F. Goodrich Co., 1247 S. High St., Akron, Ohio.

Vibration-Resistant Coupling

Body and nut of this coupling are 17ST aluminum alloy forging or bar stock, anodically treated to inhibit corrosion. Flexible compression sleeves are a synthetic rubber suitable for wide variation in temperature and type of fluids employed. Two of these sleeves, metal bushed at either end, are encased in two nuts which bear against the body of the fitting, such as an elbow or T. Compression sleeves provide the sealing medium while nuts sustain mechanical forces applied in tightening couplings. Metallic end bushings of the compression sleeves confine and protect the synthetic rubber from contamination and



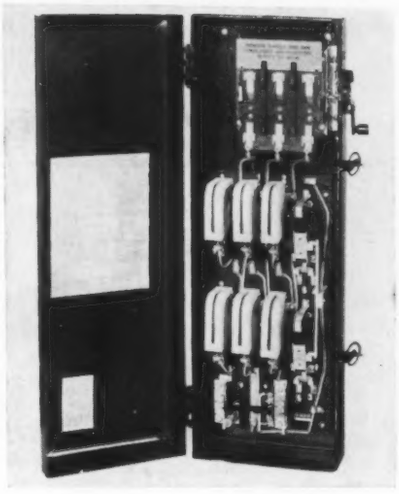
provide bearing area against the tube, nut and body of the fittings. Under mechanical tightening pressure, the compression sleeve conforms to the outer wall of the tube and angular faces of the body and compression nut. A clearance slot in the metal end bushings permits use of the coupling with tubing of varying diameters. Tubing used with this coupling should be flared as indicated, and a small locking ring installed to prevent axial pull-out. A flare of 12 deg. is said to develop the full burst strength of 52S aluminum alloy tubing conforming to army and navy standards. Perfectly formed flares are not necessary since the rubber sleeve forms the seal, and the flare cannot be sheared off by repeated tightenings of the compression nut. Raybould Coupling Co., Meadville, Pa.

Resistance Welder Control

In the "Sayfront" resistance welder control, all electrically energized parts are behind a protective panel to eliminate any danger of shock while timing adjustments are being made. Calibrated timer adjustments are accessible on the panel front. The unit has a separate pneumatic timing device for each step of the welding cycle, with periods from 3 to 100 cycles obtained by turning a small knurled wheel. To expose operating parts, the interior swings out, and a separable connector allows panel removal without disturbing external connections. Timers and relays can be serviced with standard tools. Industrial Controller Div., Square D Co., 4041 N. Richards St., Milwaukee, Wis.

Combination Magnetic Reversing Starters

Full-voltage starting and reversing control and short circuit protection are provided in one unit for squirrel cage induction motors. Units are also suitable for primary control of wound-rotor motors. They consist of two mechanically interlocked reversing contactors, two-pole overload relay, and either a circuit breaker or fusible or non-fusible motor circuit switch. The line includes N.E.M.A. size 0 to 4 starters covering single-phase and three-phase motors in sizes up to and including 100 hp. at 440 or 550 volts. Fusible forms combine manually operated motor circuit switch with clips for cart-



ridge type fuses. Trip handle is so interlocked with the cover that the switch must be in the "off" position before the cover can be opened. Circuit breaker forms have simultaneous trippings of all phases on short circuits. A trip-free mechanism prevents holding the breaker closed under short-circuit conditions. In smaller ratings, breakers have bimetal thermal trip units only. Larger breaker ratings have interchangeable bimetal thermal trip as well as magnetic instantaneous trip. Undervoltage protection for starters used in conjunction with momentary contact pushbutton stations is provided by electrical interlock on each contactor. Isothermic temperature overload relay protects the motor from dangerous overheating. Contactors are mechanically interlocked so that only one can be closed at a time. General Electric Co., Schenectady, N. Y.

Synthetic Hard Rubber

According to the manufacturer's report, a new Ameripol hard rubber will withstand temperatures 100 deg. F. higher before softening than will the best hard rubber made from natural crude. Material may be molded or extruded. The B. F. Goodrich Co., Akron, Ohio.

Books and Bulletins

Aircraft Engine Design

JOSEPH LISTON—*486 pages, 6x9 in., indexed. Green buckram covers. Published by the McGraw-Hill Book Co., 300 West 42nd St., New York, N. Y. Price $4.50.*

Complete with suggested design procedures, references, and practical problems, this textbook has been written for the student's use in the transition period between fundamental, technical background and practicing aircraft engine design. It is the author's intention to acquaint readers with considerations in the design of conventional aircraft engines so that this knowledge can be used as a basis for advance design projects.

Introductory chapters deal with basic requirements, possibilities and limitations, and a suggested project outline. Mechanical considerations include gas-pressure forces; analyses of forces and stresses in the crank chain; bearing loads; design considerations for reciprocating parts; crankshaft vibration and balance; design details of crankshaft and reduction gearing, cylinders, valves, valve gear, crankcase, superchargers and essential accessories.

Basic formulas for the most part are given without derivations. Calculations are aided by diagrams, and illustrations include line drawings and photographs.

There are three appendices. The first contains 51 tables of reference information, condensed design considerations, drawings and data on standard parts. The second consists of properties of materials used in aircraft engines. Appendix 3 has useful design formulas, definitions and tables.

Production Engineering

EARLE BUCKINGHAM—*268 pages, 6x9 in. Blue buckram covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price $2.50.*

Coordination of basic studies such as mathematics, physics, chemistry and mechanics with such specific subjects as machine design, materials and power is necessary for an effective, broad perspective on production engineering. That is the theme upon which this text was written.

The three main divisions are: (1) "Preparation for Production," (2) "Production Operation and Control," and (3) "Supporting Activities." Under the first heading are considered production design, equipment planning, tool design and proving. In the second section are matters relating to operation—production, cost and material control, personnel, procurement, records, etc. Subjects in the third part include standardization of materials, processes, tools, machines, methods and designs, a chapter on costs and one on development. In the final summary is a suggested production organization.

Modern Plywood

THOMAS D. PERRY—*366 pages, 6x9 in. Plywood covers. Published by Pitman Publishing Corp., 2 West 45th St., New York, N. Y. Price $4.50.*

Clear, brief delineation of the earlier and modern technique involved in the manufacture and application of plywood in industry. The author has drawn generously from many authoritative sources for his material to compile and prepare this timely volume.

Sections allotted to the glossary and the economic advantages that are to be obtained through the use of plywood serve as a splendid introduction to the descriptions which follow. The chapter on adhesives for plywood deals with all types. Methods of fabricating are also described. Of especial interest to engineers is the voluminous data on physical properties, characteristics and types of plywood that are available as standard materials for a wide and increasing range of industrial uses.

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Manual of Spring Engineering

Spiral bound, red leatherette covers. 132 pages, 8½x11 in., indexed. Published by American Steel & Wire Co., Rockefeller Building, Cleveland, Ohio. Price $1.00.

Here is a wealth of information on spring design, well illustrated and effectively laid out. In the first part of the book is useful background material on spring production and specifications. Included under the title of "Spring Materials" are sections on steels for springs, treating of steels for springs, physical properties (2-page table), fatigue characteristics, corrosion considerations, and effect of temperature.

An outstanding feature is a series of nomographic charts for calculations in the design of springs in each broad classification—helical extension and compression, helical torsion, and flat spiral or motor springs. In each section there is discussion of vital factors in the design of that type. Formulas are given and methods of computing with charts explained.

Photographs show springs and typical applications. Line sketches are used with effect in indicating spring elements and types of end formations.

A large appendix contains essential tables of such data as allowable stresses, tolerances, length and coil variations, weights of springs, gauge numbers, diameters and areas, and weights of cold rolled strip steel.

Tin Research

Publication No. 109, 12 pages, 6x9 in. Published by Tin Research Institute, Fraser Road, Greenford, Middlesex, England.

An annual report for 1941, this booklet summarizes recent researches and developments in the uses of tin. It lists several recent publications of the institute and deals briefly with various advances in tin coating methods. There are also discussions of bearing metals, foils, tin containing bronzes, and chemical compounds of tin used in the vitreous enamel and textile industries.

Moments of Inertia And Section Moduli

Mathematical Tables Project—197 pages, 8x10¼ in., green clothbound covers. Published by the National Bureau of Standards, U. S. Dept. of Commerce, Washington, D. C. Price $1.25.

The complete title of this volume is "Tables of the Moment of Inertia and Section Modulus of Ordinary Angles, Channels, and Bulb Angles with Certain Plate Combinations." The tables cover combinations of ordinary angles with heel-to-plate, ordinary angles with toe-to-plate, various channel sections with flange-to-plate, and bulb angles with foot-to-plate. Tables also included list properties of plates, ordinary angles, channels, and bulb angles.

Collapsing Pressure Of Thin-Walled Cylinders

ROLLAND G. STURM—*University of Illinois Engineering Experiment Station Bulletin Series No. 329. Paper covers, 80 pages, 6x9 in. Published by the University of Illinois, Urbana, Ill. Price 80 cents.*

Results of a study having for its purpose an analysis of the elastic behavior of thin circular cylindrical shells subjected to uniform external pressure and to determine the pressure at which such shells collapse for simply supported and for fixed edges, extensions in the analysis are made for plastic behavior of the material, for "out-of-roundness" of the cylinder, and for stiffening effects of ring stiffeners. Another purpose was to study experimentally the behavior of thin-walled tubes under uniform external pressures, for comparison with the results of the theoretical analysis.

SPECIFICATION NUMBERS FOR COPPER ALLOYS – I

R. A. WILKINS and E. S. BUNN
Revere Copper and Brass Incorporated

THREE CLASSES of materials—(1) wire, rod and bar shapes, (2) plate, sheet and strip, and (3) tube and pipe—are given under each of 28 commonly used materials. Specifications for cast alloys are not included.

Numbers in parenthesis at left in each column are not part of specification numbers. Same numbers beside two or more specifications indicate close similarity or interchangeability.

Frankford Arsenal specifications are distinguished from the Army specifications by the prefix FXS in second column.

Naval Torpedo Station specifications are distinguished from the Navy specifications by being an 800 series.

Federal	U. S. Army and Frankford Arsenal	U. S. Navy and Naval Torpedo Sta.	ASTM	ASME—SAE AMS—British
Electrolytic Copper (Tough Pitch) (Copper 99.90% Min.)				
WIRE, ROD AND BAR (SHAPES)				
(1) QQ-W-341 (2) QQ-W-336 (3) QQ-C-501a	(1) 57-222-1 (2) 57-219 (4) 71-290	(1) 22-W-9a (2) 22-W-3c (3) 47-C-2f	(1) B3-41 (2) B1-40 (3) B133-40T (5) B33-39 (6) B47-39 (7) B105-39 (8) B12-33 (9) B2-40 (10) B48-40T (11) B49-41 (12) B124-41T (12)	(1) 83 (SAE) (7) S-21 (ASME)
PLATE, SHEET AND STRIP				
(1) QQ-C-501a	(2) 57-226	(1) 47-C-2f (3) 43-B-8a	(1) B152-41T (A) (2) B11-41 (1) (5) B101-40	(1) 71 (SAE) (1) 4500 (AMS) (2) S-20 (ASME) (4) 899 (Brit.)
TUBE AND PIPE				
(1) WW-P-377 (2) WW-P-378 (3) WW-T-797 (4) WW-T-799 (5) WW-P-541a	(1) 57-188-A (3) 57-188-A (6) 50-27-1B (6) FXS-22 (7) 57-173-B	(1) 44-P-2g (3) 44-T-12c (3) 889 (11) SGS-48-39B	(8) B11-40T (9) B13-41	(1) S-23 (ASME) (8) S-47 (ASME) (9) S-22 (ASME) (10) 75 (SAE)
Phosphorus Deoxidized Copper (Cu 99.9% Min., Ph 0.025%)				
WIRE, ROD AND BAR (SHAPES)				
(1) QQ-C-501a	(2) 57-222-1 (3) 71-290	(1) 47-C-2f	(1) B133-40T (4) B124-41T (12) (5) B48-40T (6) B12-33	(6) S-21 (ASME)
PLATE, SHEET AND STRIP				
(1) QQ-C-501a	(2) 57-226	(1) 47-C-2f (3) 43-B-8a	(1) B152-41T (B) (2) B11-41 (2) (5) B101-40	(1) 71 (SAE) (1) 4500 (AMS) (2) S-20 (ASME) (4) 899 (Brit.)
TUBE AND PIPE				
(1) WW-P-377 (2) WW-P-378 (3) WW-P-541a (4) WW-T-797 (5) WW-T-799	(1) 57-188A (4) 57-188A (6) 50-27-1B (A) (6) FXS-22	(1) 44-P-2g (4) 44-T-12C (4) 889 (7) SGS-48-39B	(1) B42-41T (9) B13-41 (10) B111-40T (4) B88-41 (11) B75-41T (B) (12) B68-41T (B)	(1) S-23 (ASME) (8) 899 (Brit.) (9) S-22 (ASME) (10) S-47 (ASME) (11) 75 (SAE)

SPECIFICATION NUMBERS FOR COPPER ALLOYS (continued)

Federal	U. S. Army and Frankford Arsenal	U. S. Navy and Naval Torpedo Sta.	ASTM	ASME—SAE AMS—British
High Conductivity Oxygen Free Copper (Cu 99.4% Min.)				
WIRE, ROD AND BAR SHAPES				
(1) QQ-W-341 (2) QQ-W-336 (3) QQ-W-501a	(1) 57-222-1 (2) 57-219 (4) 71-290 (5) 57-154-1A	(1) 22-W-9a (2) 22-W-3c (3) 47-C-2f	(1) B3-41 (2) B1-40 (3) B133-40T (6) B12-33 (7) B33-39 (8) B48-40T (9) B47-39 (10) B49-41 (11) B124-41T(12) (12) B105-39 (13) B2-40	(1) 83 (SAE) (6) S-21 (ASME)
PLATE, SHEET AND STRIP				
(1) QQ-C-501a	(2) 57-226	(1) 47-C-2f (3) 43-B-8a	(1) B152-41T(C) (2) B11-41(1) (5) B101-40	(1) 71 (SAE) (1) 4500 (AMS) (2) S-20 (ASME) (4) 899 (Brit.)
TUBE AND PIPE				
(1) WW-P-377 (2) WW-P-378 (3) WW-T-797 (4) WW-T-799 (5) WW-P-541a	(1) 57-188A (3) 57-188A (6) 50-27-1B(A) (6) FXS-22	(1) 44-P-2G (3) 44-T-12C (3) 889 (7) SGS-48-39B	(1) B42-41T (4) B88-41 (8) B13-41 (9) B111-40T (10) B75-41T(D) (11) B68-41T(D)	(1) S-23 (ASME) (8) S-22 (ASME) (9) S-47 (ASME) (10) 75 (SAE)
Silver Bearing Copper (Silver—10 Oz. Per Ton)				
WIRE, ROD AND BAR (SHAPES)				
(1) QQ-W-341 (2) QQ-W-336 (3) QQ-C-501a	(1) 57-222-1 (2) 57-219 (4) 71-290	(1) 22-W-9a (2) 22-W-3c (3) 47-C-2f	(1) B3-41 (2) B1-40 (3) B133-40T (5) B12-33 (6) B33-39 (7) B48-40T (8) B47-39 (9) B49-41 (10) B124-41T(12) (11) B105-39 (12) B2-40	(1) 83 (SAE) (5) S-21 (ASME)
PLATE, SHEET AND STRIP				
(1) QQ-C-501a	(2) 57-226	(1) 47-C-2f (3) 43-B-8a	(1) B152-41T(D) (2) B11-41(1) (5) B101-40	(1) 71 (SAE) (1) 4500 (AMS) (2) S-20 (ASME) (4) 899 (Brit.)
TUBE AND PIPE				
(1) WW-P-377 (2) WW-P-378 (3) WW-T-797 (4) WW-T-799 (5) WW-P-541a	(1) 57-188A (3) 57-188A (6) 50-27-1B(A) (6) FXS-22	(1) 44-P-2g (3) 44-T-12C (3) 889 (7) SGS-48-39B	(1) B42-41T (8) B13-41 (9) B111-40T (10) B68-41T	(1) S-23 (ASME) (8) S-22 (ASME) (9) S-47 (ASME) (11) 75 (SAE)
Gilding Metal (Copper—95%, Zinc—Balance)				
WIRE, ROD AND BAR (SHAPES)				
			(1) B134-41T(1)	
PLATE, SHEET AND STRIP				
	(1) 57-171-2	(1) 819	(1) B36-41T(1)	

SPECIFICATION NUMBERS FOR COPPER ALLOYS (continued)

Federal	U. S. Army and Frankford Arsenal	U. S. Navy and Naval Torpedo Sta.	ASTM	ASME—SAE AMS—British
Commercial Bronze (Government Gilding Metal) (Cu 90%, Zn Balance)				
WIRE, ROD AND BAR (SHAPES)				
	(1) 57–171		(2) B134–41(2)	
PLATE, SHEET AND STRIP				
	(1) 57–171 (2) 57–171–1B (2) FXS–277 (3) 57–171–3 (3) FXS–281		(1) B36–41T(2) (2) B130–41T (3) B131–40T	
TUBE AND PIPE				
	(1) 50–27–1B(B) (1) FXS–21		(2) B111–40T	(2) S–47 (ASME)
Rich Low Brass (Cu 85%, Zn Balance)				
WIRE, ROD AND BAR (SHAPES)				
(1) WW–P–541a(F)		(2) 45–F–2 (int)	(3) B134–41T(2)	
PLATE, SHEET AND STRIP				
(1) WW–P–541a(F)	(2) 57–160		(2) B36–41T(3)	(2) 79–A (SAE)
TUBE AND PIPE				
(1) WW–P–541a(F) (2) WW–P–448 (3) WW–P–351(A) (4) WW–T–791(1)	(3) 83–5A(A) (4) 57–190(1)	(3) 44–P–12c(A) (4) 44–T–15b(1) (5) 44–T–16a	(3) B43–41 (4) B135–40T(1) (6) B111–40T	(3) S–24 (ASME) (6) S–47 (ASME) (7) S–27 (ASME) (8) 74 (SAE)
Low Brass (Cu 80%, Zn-Balance)				
WIRE, ROD AND BAR (SHAPES)				
(1) WW–P–541a	(2) 57–217A		(3) B134–41T(2)	
PLATE, SHEET AND STRIP				
(1) WW–P–541a	(2) 57–160 (3) 57–229–A		(2) B36–41T(4)	(2) 79–B (SAE)
TUBE AND PIPE				
(1) WW–P–541a	(2) 57–189 (3) 83–5A(A)		(4) B14–18	
Cartridge Brass (Cu 70%, Zn-Balance)				
WIRE, ROD AND BAR (SHAPES)				
(1) WW–P–541a (2) QQ–W–321			(3) B134–41T(2)	
PLATE, SHEET AND STRIP				
(1) QQ–B–611a(E) (2) WW–P–541a	(1) 57–172–1C (1) FXS–279 (3) 57–172–2A (3) FXS–267 (4) 57–173–B (4) FXS–278 (5) 50–46–1B	(6) OS–1051 (6) 861	(1) B36–41T(6) (3) B129–40T (4) B19–41T	(1) 70–A (SAE)
TUBE AND PIPE				
(1) WW–P–541a			(2) B135–40T(2) (3) B14–18	(4) 4555 (AMS)

SPECIFICATION NUMBERS FOR COPPER ALLOYS (continued)

Federal	U. S. Army and Frankford Arsenal	U. S. Navy and Naval Torpedo Sta.	ASTM	ASME—SAE AMS—British
High (Yellow) Brass (Cu 66%, Zn-Balance)				
WIRE, ROD AND BAR (SHAPES)				
(1) QQ–B–611a(C) (2) QQ–W–321 (A&B) (3) WW–P–541a		(1) 47–B–2 (int) (1) 817	(4) B134–41T(2)	(2) 80(B) (SAE)
PLATE, SHEET AND STRIP				
(1) QQ–B–611a(C) (2) WW–P–541a	(3) 47–B–2 (int) (4) 34–T–1e		(5) B36–41T(7)	(1) 70(C) (SAE) (5) 4505 (AMS)
TUBE AND PIPE				
(1) WW–P–351(B&C) (2) WW–T–791(2&3) (3) WW–P–541a	(1) 83–5A(B&C) (2) 57–189(c) (2) 57–190(2&3)	(1) 44–P–12c(B) (2) 44–T–15b(2) (4) 47–B–2 (int) (6) 44–T–5C	(2) B43–41	(2) S–24 (ASME) (5) 4555 (AMS)
Muntz Metal (Cu 60%, Zn-Balance)				
WIRE, ROD AND BAR (SHAPES)				
(1) WW–P–541a		(2) 47–B–2 (int)	(3) B124–41T(1)	(4) 82 (SAE) (4) 250 (Brit.)
PLATE, SHEET AND STRIP				
(1) QQ–B–611a(D) (2) WW–P–541a			(3) B57–27	(3) S–59 (ASME)
TUBE AND PIPE				
(1) WW–P–351(C) (2) WW–T–791(3) (3) WW–P–541a	(1) 83–5a(C) (2) 57–190(3) (4) 57–189(B&D)	(5) 44–T–5C	(1) B43–41 (2) B135–40T(5) (6) B111–40T	(1) S–24 (ASME) (6) S–47 (ASME) (7) S–27 (ASME) (8) 74 (SAE)
Leaded High Brass (Cu 65.5%, Pb 0.90%, Zn Balance)				
WIRE, ROD AND BAR (SHAPES)				
(1) WW–P–541a(C&D)		(2) 47–B–2 (int) (2) 817 (3) 34–T–1e		
PLATE, SHEET AND STRIP				
(1) QQ–B–611a(D) (2) WW–P–541a(C&D)		(1) 47–B–2 (int) (3) 34–T–1e	(4) B121–41T(3)	
TUBE AND PIPE (CU 66.5%, PB 0.60%, FE 0.70%, ZN BALANCE)				
(1) WW–P–541(C&D)		(2) 44–T–5C		
Heavy Leaded Brass (Cu 64%, Pb 2.5%, Zn Balance)				
WIRE, ROD AND BAR (SHAPES)				
(1) WW–P–541a(D)		(2) 47–B–2 (int)		
PLATE, SHEET AND STRIP				
(1) QQ–B–611a(D) (2) WW–P–541a(C&D)		(1) 47–B–2 (int) (3) 34–T–1e	(4) B121–41T(6)	
TUBE AND PIPE (CU 66.5%, PB 1.50%, FE 0.70%, ZN BALANCE)				
(1) WW–P–541a(D)	(2) FXS–205(Rev–2)			